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CONTENTS

Control of Sweetpotato Weevils and Vine Borer in Hawaii ..... Martin Sherman and Wallace C. Mitchell 389
Currant Borer Control Studies ..... E. F. Taschenberg 394
Bioclimatic Studies of Oriental Fruit Fly in Hawaii ..... N. E. Flitters and P. S. Messenger 401
Fly Control with a New Bait Application Method ..... R. K. Thompson, A. A. Whipp, D. L. Davis, and Edward G. Batte 404
An Urban Fly Control Campaign ..... C. C. Burkhardt and Paul A. Dahm 409
DDT and Other New Insecticides for Codling Moth Control in the Pacific Northwest ..... E. J. Newcomer and F. P. Dean 414
A Laboratory Method for Testing Repellents against Biting Flies ..... Eleanor B. Starnes and Philip Granett 420
Efficiency of Sulfhydril Compounds in the Detoxication of Arsenite in Two Species of Insects ..... Ann D. Anderson and R. L. Patton 423
Insecticidal Control of Rhodes Grass Scale on St. Augustine Grass Lawns ..... B. H. Richardson 426
Control of Immature Stages of the Boll Weevil ..... M. J. Lukefahr and J. C. Gaines 430
Insecticidally Treated Seed for Wireworm Control ..... Walter M. Kulash 433
New Acaracides Against Mites Attacking Nursery Plants . Clyde C. Hamilton 442
Persistence of DDT in Soils of the Area Infested by the Japanese Beetle ..... Walter E. Fleming and Warren W. Maines 445
Life History and Control of Pecan Spittlebug ..... S. C. Chandler 450
Torsalo and Tick Control with Toxaphene in Central America ..... Ernest W. Laake 454
Food Habits of Coniopterygids on Citrus in Southern California ..... C. A. Fleschner and D. W. Ricker 458
Insecticidal Control Plot Tests for Pea Aphids in Relation to Alfalfa Hay Yields ..... W. W. Franklin 462
Effect of Successive Treatments of DDT on Individual Susceptibility in the American Cockroach ..... Shen Chin Chang and H. H. Crowell 467
Radioisotopes as Tracers in Plum Curculio Behavior Studies ..... Roy W. Rings and George W. Layne, Jr. 473
Continuous Laboratory Propagation of Western Grape Leaf Sketetonizer and Parasites by Prevention of Diapause ..... Owen J. Smith and Robert L. Langston 477
Host Relationship Studies of *Lygus* in South Central Washington ..... David R. Malcolm 485
Cucumber Beetles Attacking Melons in Northern California ..... A. E. Michelbacher, W. W. Middlekauff and O. G. Bacon 489
Distribution and Control of Forbes Scale in the Midwest ..... D. W. Hamilton and S. A. Summerland 494
Fringe Benefits from Plant Quarantines ..... Ralph W. Sherman 499
Acaricides for Control of Tomato Russet Mite in California ..... T. O. Tuft and L. D. Anderson 502

SCIENTIFIC NOTES:

A Strepsipteran Parasite of the Three-Cornered Alfalfa Hopper ..... C. R. JORDAN 505
DDT, Methoxychlor and Pyrethrins-Piperonyl Butoxide Against the Hairy Spider Beetle in Warehouses ..... F. L. WATTERS AND B. N. SMALLMAN 505
Timing Plum Curculio Sprays on Apple ..... STEWART C. CHANDLER 506
Effect of Fertilizer on Rice Weevil Damage to Corn at Harvest ..... W. G. EDEN 509
Leafhopper Control with Methoxychlor and Parathion to Increase Alfalfa Hay Production ..... J. T. MEDLER AND E. H. FISHER 511
Enzymatic Dehydrochlorination of DDT by Resistant Flies ..... JAMES STERNBURG, EDDIE B. VINSON AND C. W. KEARNS 513
Sponging Method of Earworm Control in Texas ..... GEORGE P. WENE AND R. A. BLANCHARD 515
Residual Effectiveness of DDT Sprays against Mosquito Breeding in Alaska ..... K. H. APPLEWHITE, H. L. KEEGAN AND R. A. HEDEEN 516
Residual Effectiveness of Some Organic Insecticides in Control of Japanese Beetle Larvae ..... J. B. POLIVKA 517
A Spotted Tentiform Leaf Miner Outbreak in California Orchards ..... ARTHUR D. BORDEN, WM. H. LANGE AND HAROLD F. MADSEN 519
Small-Plot Tests of New Insecticides in Control of European Corn Borer, 1950–51 ..... D. D. QUESTEL AND TOM A. BRINDLEY 519
Sugar Concentration of Some Massachusetts Honey Plants ..... F. R. SHAW, T. H. FARR AND H. L. GOLDSTEIN 521
Rearing Stable Fly for Laboratory Tests ..... E. J. CAMPAU, G. J. BAKER AND F. D. MORRISON 524
Scientific Names of Body and Head Lice ..... C. F. W. MUESEBECK 524
A Tactile Ovipositional Stimulus to Culture *Macrocentrus ancylivorus* on an Unnatural Host ..... BLAIR R. BARTLETT 525
Use of a Virus Disease to Control European Pine Sawfly ..... PHILIP B. DOWDEN AND HAROLD B. GIRTH 525
On the Systemic Action of Systox on Cotton ..... DONALD W. DAVIS AND A. C. SESSIONS 526
Tinea fuscipunctella Associated with *Tyroglyphus lintneri* ..... V. G. MILUM 527
Termite Treatment with One Per Cent Solution of Chlordane ..... V. E. SHELFORD 527
DDT-Resistance and Its Inheritance in the House Fly ..... C. MARY HARRISON 528
Ectoparasites from Mammals at Camp Lejeune ..... TED TIBBETTS 530
"CAPTAN" A New Coined Name ..... H. L. HALLER AND S. W. SIMMONS 531

OBITUARIES:

William Randolph Walton 533
Clarence R. Cleveland 538

PROCEEDINGS 534
BOOK REVIEWS 539

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Control of Sweetpotato Weevils and Vine Borer in Hawaii[1]

MARTIN SHERMAN and WALLACE C. MITCHELL[2,3] *University of Hawaii, Agricultural Experiment Station*

The West Indian sweetpotato weevil, *Euscepes postfasciatus* (Fairm.), the sweetpotato weevil, *Cylas formicarius elegantulus* (Summers), and the sweetpotato vine borer, *Omphisa anastomosalis* (Guen.) are the most destructive insect pests of sweetpotatoes in Hawaii. In the period prior to the development of the synthetic organic insecticides, moderate control of these pests was obtained by the use of arsenicals or cryolite in combination with good cultural and sanitary practices (Tucker 1937; Holdaway 1941). Sherman (1951) compared the use of cryolite with DDT and seven other synthetic organic insecticides for control of these sweetpotato insects and found that the use of DDT as a pre-planting dip for the sweetpotato cuttings followed by 5 spray applications during the season gave excellent control.

Since DDT was effective, is readily available to growers, and is comparatively inexpensive, field plot experiments were conducted in 1951 and 1952 on the island of Oahu to find the most efficient methods of applying DDT sprays and dusts to control the weevils and vine borer. In these experiments both the concentration of DDT and the number of applications during the season were varied. Two trials were also carried out to determine the effectiveness of DDT and five other organic insecticides when applied to the soil in controlling the two species of weevils.[4]

A weevil-susceptible variety of sweetpotato was used throughout these studies.[5] Twelve-inch terminal cuttings of the vines were used as planting material.

DDT SPRAY TRIALS.—The sweetpotato cuttings were given a pre-planting dip in a suspension of 2 pounds of actual DDT per 100 gallons. A commercial depositing agent and sticker[6] was added to the dip suspension at the rate of 1:2000.

Three concentrations of sprays were used containing 2, 1, and 0.5 pounds of DDT per 100 gallons. Each concentration was applied, 5, 3, and 2 times during the growing season. The applications in the five-spray schedule were made 5, 10, 13, 16, and 18 weeks after planting. The three-spray schedule consisted of applications 10, 13, and 16 weeks after planting, whereas the applications in the two-spray schedule were made 10 and 16 weeks after planting. The rapid build-up of a mite[7] on the plants sprayed with DDT 5 weeks after planting necessitated the addition of 6 pounds of 95 per cent wettable sulfur per 100 gallons to all subsequent DDT sprays. The sprays were applied at the rate of 250 to 320 gallons per acre with a 150 gallon power sprayer maintained at an operating pressure of 250 pounds per square inch. Emphasis was placed on spraying the lower portion of the main stems of the plants and the surrounding soil.

Each experimental plot was 500 square feet in area. All plots contained four irrigation furrows in each of which 40 cuttings were planted at 6-inch intervals on February 27, 1951. The treatments were randomized and replicated four times.

[1] Published with the approval of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 282.

[2] Akira Kubota and Minoru Tamashiro assisted in carrying out the experiments.

[3] Presented at the Pacific Branch Meetings of the American Association of Economic Entomologists, Santa Barbara, California, June 1952.

[4] The following manufacturers supplied experimental materials: California Spray-Chemical Corp., Richmond, Calif.; General Chemical Division, Allied Chemical and Dye Corp., New York; Julius Hyman and Co., Denver, Colo.; Niagara Chemical Division, Food Machinery and Chemical Corp., Richmond, Calif.; Nico-Dust Manufacturing Division, Stauffer Chemical Co., San Francisco; Pacific Chemical and Fertilizer Co., Honolulu.

[5] This variety, Onalena (formerly known as HAES 14), was developed by Dr. C. F. Poole, Vegetable Crops Department, College of Agriculture, University of Hawaii. The writers are indebted to Dr. Poole and other members of the Vegetable Crops Department for supplying the planting material and the experimental land.

[6] Triton B-1956, Rohm and Haas Co., Philadelphia, Pa.

[7] *Petrobia* sp., identified by Dr. I. M. Newell, Department of Entomology, College of Agriculture, University of Hawaii.

Table 1.—Comparative effectiveness of DDT-suspension sprays in controlling two species of sweetpotato weevils, *Euscepes postfasciatus* and *Cylas formicarius elegantulus* and the sweetpotato vine borer, *Omphisa anastomosalis*.

Treatment Lbs. Actual DDT per 100 Gallons[1]	Number Sprays per Season[2]	Number Stems Examined	Number Roots Examined	Per Cent Infested		
				Stems		Roots
				Vine Borer	Weevils	Weevils
2	5	269	152	0.9	16.9	0.0
2	3	269	159	4.7	35.2	1.1
2	2	273	335	9.0	29.4	2.0
1	5	271	187	4.4	15.5	1.5
1	3	273	132	8.7	24.0	0.9
1	2	264	130	21.4	44.1	6.3
0.5	5	269	167	13.6	20.8	2.9
0.5	3	275	164	23.0	52.3	21.5
0.5	2	294	180	20.1	30.2	10.9
Check (dip treatment only)		286	104	32.6	77.4	42.3
Least difference for significance:			(19:1)—11.2	19.5	17.5	
			(99:1)—15.1	26.3	23.7	

[1] Ninety-five per cent wettable sulfur was added to all sprays at the rate of 6 pounds per 100 gallons beginning with the 10-week application.
[2] Five-spray schedule—5, 10, 13, 16, and 18 weeks after planting.
Three-spray schedule—10, 13, and 16 weeks after planting.
Two-spray schedule—10 and 16 weeks after planting.

Twenty weeks after planting (July 16 and 17, 1951) the stems and potatoes in the center two rows of each plot were harvested. The stems were cut 6 to 8 inches below the surface of the soil and approximately one-foot lengths were examined for weevil and vine borer damage. All potatoes 3 inches or more in length were examined for weevil damage.

The results of the DDT spray experiments are summarized in table 1. Thirty-three per cent of the stems in the check plots which received only a dip treatment were infested by the vine borer. The application of five sprays containing 2 pounds of actual DDT per 100 gallons resulted in 97.2 per cent control and an infestation of less than 1 per cent. The control of the vine borer decreased as the concentration and number of applications of DDT were decreased.

Seventy-seven per cent of the stems examined from the check plots were infested with weevils. All of the treatments resulted in some control but the 5-spray schedule gave the best protection from

Table 2.—Comparative effectiveness of DDT dusts in controlling two species of sweetpotato weevils, *Euscepes postfasciatus* and *Cylas formicarius elegantulus* and the sweetpotato vine borer, *Omphisa anastomosalis*.

Per Cent DDT[1]	Number Applications per Season[2]	Number Stems Examined	Number Roots Examined	Per Cent Infested		
				Stems		Roots
				Vine Borer	Weevils	Weevils
5	5	136	452	24.8	99.4	9.1
5	3	167	409	24.9	100.0	19.8
5	2	131	329	29.1	99.1	30.5
2	5	157	379	34.6	99.4	28.0
2	3	144	397	25.0	100.0	43.8
2	2	136	422	27.4	100.0	57.9
Check (dip treatment only)		147	333	43.1	100.0	57.9
Least difference for significance:[3]			(19:1)—N.S.	N.S.	12.9	
			(99:1)—N.S.	N.S.	17.7	

[1] Each DDT dust contained 50 per cent sulfur.
[2] Five-dust schedule—5, 10, 13, 16 and 18 weeks after planting.
Three-dust schedule—10, 13 and 16 weeks after planting.
Two-dust schedule—10 and 16 weeks after planting.
N.S.—No significant difference.

Table 3.—Comparative effectiveness of insecticides in controlling two species of sweetpotato weevils, *Euscepes postfasciatus* and *Cylas formicarius elegantulus*, when applied as cutting dips and soil treatments. Experiment A, Poamoho, Oahu, 1950.

Material	Pounds Actual per Acre	Number Stems Examined	Number Roots Examined	Per Cent Infested Stems	Per Cent Infested Roots
Lindane	5.0	111	348	10.0	12.6
	2.5	106	347	3.8	2.6
	1.25	120	366	9.2	1.2
Aldrin	5.0	106	346	7.6	4.5
	2.5	102	373	8.3	1.2
	1.25	110	408	13.1	2.3
Dieldrin	5.0	116	352	3.4	2.7
	2.5	111	349	11.6	4.0
	1.25	114	293	7.0	9.0
Chlordane	5.0	114	412	7.9	4.7
	2.5	110	344	9.9	5.3
	1.25	114	335	12.4	2.4
Parathion	5.0	108	342	16.0	2.8
	2.5	98	399	26.1	3.9
	1.25	111	342	41.3	8.2
Check (untreated)		107	343	69.0	16.9
Least difference for significance:				(19:1)—24.5 (99:1)—33.0	7.1 9.6

these insects regardless of the concentration of the spray applied.

Over 40 per cent of the sweetpotatoes harvested from the check plots which had received only the dip treatment were infested with weevils. All of the spray treatments except those in the 2- and 3-spray schedules applied at 0.5 pound per 100 gallons resulted in excellent control.

DDT Dust Trials.—As many sweetpotato growers find it inconvenient to use sprays for the control of the sweetpotato weevils and vine borer, an experiment was conducted to determine whether DDT dusts could be substituted for sprays satisfactorily. All cuttings were given the preplanting dip in a suspension of 2 pounds of actual DDT per 100 gallons just prior to planting on January 17, 1952.

DDT dusts were used at 5 and 2 per cent concentrations. The dusts were prepared by diluting a 10 per cent DDT dust concentrate with pyrophyllite and dusting sulfur in such proportion that each experimental dust contained 50 per cent sulfur. Each concentration was applied 5, 3, and 2 times during the season as in the spray trials. The dusts were applied with a knapsack bellows duster at the rate of 14 to 41 pounds per acre. The dust was concentrated at the base of the plants by keeping the nozzle beneath the level of the leaves.

Each experimental plot was 500 square feet in area. All plots contained four rows with 30 plants in each. The treatments were randomized and replicated four times.

Twenty weeks after planting, the main stems and the sweetpotatoes in the center two rows of each plot were harvested (June 22, 1952). The same methods of harvesting and recording damage were used as in the spray trials.

The results of the DDT dust experiment are given in table 2. The dusts were not as effective as the sprays in controlling the weevils and the vine borer. Forty-three per cent of the stems in the untreated check plots were infested with the vine borer. Although treatment reduced the infestation somewhat, the maximum control obtained was only 42.5 per cent.

The use of dusts had no effect on the weevil infestation in the stems. Approximately 100 per cent of the stems were infested regardless of the treatment.

Fifty-eight per cent of the sweetpotatoes in the untreated plots were infested with weevils. Five applications of a 5 per cent dust resulted in 84 per cent control whereas the 2 per cent dust was ineffective in all of the schedules.

The DDT dusts were not as effective as the sprays in controlling the weevils and vine borer. With ordinary methods of dusting, the lack of penetrability of the dust through the dense sweetpotato

Table 4.—Effectiveness of insecticides in controlling two species of sweetpotato weevils, Euscepes postfasciatus and Cylas formicarius elegantulus when applied as soil treatments. Experiment B, Waimanalo, Oahu, 1951.

Material	Pounds Actual per Acre	Number Roots Examined	Per Cent Infested Roots
DDT	10	315	5.9
	5	316	10.3
	2.5	336	8.3
Lindane	5	343	18.3
	2.5	427	16.6
	1.25	310	16.8
Aldrin	2.5	377	18.2
	1.25	341	16.3
Dieldrin	5	288	5.9
	2.5	295	12.7
Chlordane	5	298	40.1
	1.25	286	19.3
Parathion	5	345	17.5
	2.5	321	18.6
Check (untreated)		324	24.4

Least difference for significance: (19:1)—14.9
(99:1)—20.1

foliage would handicap its effectiveness. In this study, the dust nozzle was kept beneath the foliage canopy to overcome this factor. Despite this precaution, effective control was not obtained.

Soil Trials.—Two soil-treatment experiments were carried out in 1950 and 1951. Experiment A was conducted at the experimental farm at Poamoho while Experiment B was conducted at the experimental farm at Waimanalo.

In Experiment A, 5 per cent dusts were prepared by diluting commercial formulations of lindane, chlordane, aldrin, and dieldrin with pyrophyllite. These insecticidal dusts were applied to the surface of the soil by means of a No. 10 tin can, the bottom of which was perforated with a series of small holes. Parathion was applied as a water suspension with a wheelbarrow power sprayer. Each material was applied to a plot area of 500 square feet at the rate of 5, 2.5, and 1.25 pounds of active ingredient per acre. After application to the surface, the insecticides were mixed with the upper 2 to 3 inches of soil by hand-hoeing. The treatments were randomized and replicated three times.

The sweetpotato cuttings were planted on July 12, 1950, one week after the soil treatments were made. All plots contained 4 rows of 22 plants each. Prior to planting, all cuttings except those in the check plots were dipped in a suspension of the same insecticide used to treat the soil of that experimental plot. The dip-suspensions of aldrin, dieldrin, lindane, and parathion contained 0.031 per cent active ingredients while the chlordane dip contained 0.25 per cent. A commerical depositing agent and sticker[6] was added to the dip suspensions at the rate of 1:2000.

Twenty-two weeks (December 13 to 15, 1950) after planting, the stems and roots of the two center rows of each plot were harvested. Table 3 summarizes the results obtained in Experiment A by the various soil treatments. The weevil infestation in the stems of the treated plots was significantly less than in the untreated check plots.

All treatments except lindane at 5 pounds per acre resulted in a lower root infestation than in the untreated check plots.

The sweetpotatoes harvested from this experiment were cleaned and cured. Taste panels[8] were held on January 15 and 22, 1951 to determine whether any detectable off-flavors were associated with the soil-treatments. The potatoes were washed, then baked at 350° F. for 50 minutes in electric ovens which were preheated for 10 minutes prior to the baking period. The potatoes were scored for off-flavor. The results of the panel when subjected to analysis of variance showed no significant difference in flavor between potatoes from any of the treated or untreated plots.

In Experiment B, the insecticides were applied to the soil as suspensions of wettable powders with a 150 gallon power sprayer. The formulations and the concentrations used throughout this trial in terms of active ingredient per acre were: DDT (50 per cent wettable powder) 10, 5, and 2.5 pounds; lindane (25 per cent wettable powder) 5, 2.5, and 1.25 pounds; aldrin (25 per cent wettable powder) 2.5 and 1.25 pounds, dieldrin (25 per cent wettable powder) 5 and 2.5 pounds;

[8] The authors are indebted to Miss Kathryn Orr, Nutrition Department, Agricultural Experiment Station, University of Hawaii ,for supervising the taste panel.

chlordane (40 per cent wettable powder) 5 and 2.5 pounds.

Four days prior to planting, the insecticides were sprayed on the surface of the soil and then mechanically harrowed in to a depth of 3 inches. No pre-planting dip was given to any of the cuttings which were planted on August 3, 1951. Each experimental plot was 500 square feet in area and consisted of 4 rows of 30 plants. The treatments were randomized and replicated three times.

Twenty-three weeks (January 14, 1952) after planting, the sweetpotatoes in the center two rows of each plot were harvested. In contrast to the results obtained in Experiment A, only dieldrin at 5 pounds and DDT at 10 pounds per acre significantly reduced the weevil infestation (Table 4). None of the other insecticidal soil treatments protected the potatoes from infestation.

With the exception of DDT, the same materials were tested in both soil treatment experiments. In comparing the two trials, it appears that in order to obtain control of the weevils with most of the insecticides used, a preplanting cutting dip is needed. Each material except lindane at 5 pounds per acre substantially decreased the weevil damage in Experiment A in which dips were used in addition to soil treatment. In Experiment B in which no preplanting dip was given, only DDT and dieldrin controlled the weevils. It is doubtful whether the differences in formulation or method of soil application would account for the differences in control obtained in the two experimental areas.

In any event, the use of DDT as a soil treatment gave control of the two species of weevils comparable to that obtained with DDT sprays. Since the weevils do most of their damage below the surface of the soil, DDT soil treatment is a simple efficient method of decreasing their injury. No control of the vine borer could be expected since *Omphisa anastomosalis* does not spend any of its life cycle in the soil.

SUMMARY.—Four experiments were conducted in 1950, 1951, and 1952 to determine the effectiveness of lindane, aldrin, dieldrin, chlordane, and parathion as soil treatments and DDT as sprays, dusts, and soil treatments in controlling two species of sweetpotato weevils, *Euscepes postfasciatus* (Fairm.) and *Cylas formicarius elegantulus* (Summers), and the sweetpotato vine borer, *Omphisa anastomosalis* (Guen.).

DDT at 2.0 pounds of actual per 100 gallons when applied as a cutting dip in combination with 2 sprays during the season gave excellent protection from the weevils and vine borer.

DDT dusts were inferior to sprays. The cutting dip treatment followed by 5 applications of a 5 per cent dust controlled the weevils satisfactorily but had little effect on the vine borer.

Two soil treatment experiments gave contrasting results. In one, in which the cuttings were dipped prior to planting, all of the insecticides appreciably reduced the weevil infestation while in the other, in which no preplanting cutting dips were given, only DDT at 10 pounds and dieldrin at 5 pounds of active ingredients per acre controlled the two species of weevils. No off-flavors were detected in the potatoes from the soil-treated plots.

LITERATURE CITED

Holdaway, F. G. 1941. Insects of sweetpotato and their control. Hawaii Agr. Expt. Sta. Progress Note **26**: 1–7.

Sherman, Martin. 1951. Chemical control of sweetpotato insects in Hawaii. JOUR. ECON. ENT. **44**: 652–6.

Tucker, R. W. E. 1937. The control of Scarabee (*Euscepes batata* Waterh.) in Barbados. Agr. Jour. (Barbados) **6**(4): 133–54.

Currant Borer Control Studies[1]

E. F. Taschenberg,[2] *New York State Agricultural Experiment Station, Geneva*

As the common name indicates, the currant borer, *Ramosia tupliformis*, Clerck is primarily a pest of currants. Occasionally it infests gooseberries. The borer is of considerable economic importance in the two principal red currant producing areas of New York, centered in the Hudson Valley[3] and Chautauqua County. During the period of 1946 to 1951 it was sufficiently abundant to warrant the use of a control measure. The practice commonly suggested to combat the borer is to cut out and burn infested shoots. These shoots may be identified by their weak or sickly appearance. In the writer's experience this practice is impractical in commercial plantations. The limitations are (1) the lack of sufficient labor competent to do the work and (2) the large amount of time and expense involved to make the practice effective. Furthermore, the signs and symptoms available for making a positive identification of infested canes from the exterior are not always present or readily seen. The object of the investigation initiated in 1948 was to determine if it were possible to control the borer with insecticidal treatments. The studies included preliminary observations on biology as well as both field and laboratory tests to evaluate insecticides.

Biological.—Observations on the seasonal activity of the borer were limited to Chautauqua County. The biological phases discussed are pertinent to the development of a control program and sufficient to acquaint the reader with the essential facts about the insect. The borer overwinters as a nearly mature larva. Pupation occurs within the cane in early May. Prior to pupation an exit is prepared as the larva burrows to the surface of the shoot where only a thin layer of bark remains as a cover. The adults are clear-winged moths which begin to emerge in late May or early June, depending on the season. Information on when the pupae were found and moths began to emerge is recorded in table 1. These records were obtained by sectioning shoots and surveying plantations for the presence of moths during the cooler part of the day when they are relatively inactive. The female deposits the brown eggs singly on the bark and usually near the buds. Records on the incubation period of borer eggs are presented in table 2. At a constant temperature of 80°F. the period ranged from 6 to 8 days with most of the eggs requiring 8 days for incubation. When the temperatures averaged 71.2° and 65.8°F., respectively, at day and night for a 15 day period, eggs began to hatch within 11 days and the peak was reached 13 days after deposition. The young larvae bore through the bark and woody tissue to the pith. Evidence to date shows that there is only one generation a year.

Canes infested by borers are usually one or more years old. However, shoots of the current season may be attacked. This is most common in heavily infested plantings. As is shown by the data in table 3, a single cane may support from 1 to 8 borers. The majority of shoots are infested with 1, 2 and 3 borers. Laterals arising from older canes are also attacked. The location of borers within canes and distribution in the bushes are shown in Fig. 1. It may be concluded that any cane, regardless of position within the bush, is subject to attack. The greater number of larvae are located in shoots around the periphery of the bush.

As a result of borer feeding, the pith and woody tissue, at least to a limited extent, are destroyed. Undoubtedly the injury reduces the vigor of canes and in all likehood the damage may be reflected by a decrease of yield for several seasons. In this connection it should be noted that red currant varieties produce fruit mainly on spurs of the old wood.

Field Experiments.—Field trials with sprays were carried on over a period from 1948 to 1951. All experiments were located in commercial plantings of the Wilder variety. In most blocks the bushes were dense, possessing from 12 to 20 canes per bush. The plots were five or six rows wide and each row included no

[1] Journal paper No. 896, New York State Agricultural Experiment Station, Geneva, New York, April 10, 1952.
[2] The writer wishes to acknowledge assistance provided by Mr. Donald Crowe.
[3] Personal communication R. W. Dean, New York State Agricultural Experiment Station, Poughkeepsie, New York.

fewer than 30 bushes. There were at least two replicates of each treatment in a test block. Only one insecticide was tested in a block and it was compared in schedules of one and two sprays.

Spray treatments were applied with a power sprayer operating at a pressure of 450 pounds and using a hooded boom. This accessory equipment was the same as that described for treating grapes (Taschenberg, 1948). For experimental work on currants the end curtains of the hood were lengthened. The arrangements of nozzle parts, discs and whorl plates was also modified. The boom is made up of two 7 nozzle units and each delivers spray to one side of the row. A sketch of a unit is presented in Fig. 2. It is accompanied by details on the combination of discs and whorl plates in each nozzle. The rate of application per acre was 400 gallons in 1947 and 350 gallons in other seasons.

In this investigation the initial spray was applied a certain number of days after the first moths emerged. Over a four year period the interval varied from 10 to 15 days. Besides the observations on moth emergence the daily temperatures and the data on the incubation period for borer eggs presented in this paper served as a basis for the timing of spray treatments.

Data on the effectiveness of treatments were obtained by sectioning lengthwise from 300 to 500 shoots for each treatment. Approximately two-thirds of the sample were canes with one or more laterals. The size of sample taken from a plot depended on number of replicates. Selection of canes was at random and these were cut off at the ground level. Four or six canes were taken from a bush. All samples were collected from bushes in the middle or center two rows of the plot and seven or more bushes on each end of the plot were discarded. Usually the collection of samples was delayed to late fall or early winter. The advantage of taking data at this time was that the borers were readily located and identified without the aid of a microscope. The results are calculated and presented on basis of per cent reduction in borer population.

A total of seven organic phosphorous and chlorinated hydrocarbon insecticides were evaluated. Of the group only parathion was tried for more than one season. Information on the chemical name and concentration of toxicant in the formulation is included in tables giving the results. The source of supply is recorded in footnotes which accompany the tables.

The data obtained on the efficiency of

Table 1.—Observations on pupae and moths 1948, '49, '50 and '51.

YEAR	FIRST PUPAE OBSERVED	FIRST MOTHS FOUND
1948	May 4	May 27
1949	May 5	May 26
1950	May 9	June 10
1951	May 3	June 2

Table 2.—Observations on the incubation period of borer eggs under a constant temperature of 80° F. and under varying temperatures.

	CONSTANT TEMPERATURE 80° F.				
Number days	5	6	7	8	9
Number eggs hatched	0	1	7	93	0
	Total number eggs 101				

	VARYING TEMPERATURES					
	Ave. Temp. 65.8° F. (night) and 71.2° F. (day)[1]					
Number days	10	11	12	13	14	15
Number eggs hatched	0	12	44	167	92	2
	Total number eggs 317					

[1] Average temperature for 15 day period of incubation.

Table 3.—Observations on the density of borer population in shoots taken from untreated check plots, 1948 and 1950.

BORER POPULATION PER SHOOT	SAMPLE (1948) NUMBER		SAMPLE (1950) NUMBER	
	Shoots	Borers	Shoots	Borers
1	394	394	144	144
2	192	384	103	206
3	94	282	57	171
4	29	116	22	88
5	9	45	15	75
6	3	18	11	66
7	1	7	1	7
8	1	8	0	0
Total	723	1254	353	757
Average number borers per shoot		1.7		2.1

Table 4.—Results with various spray schedules of DDT, DDD and parathion, 1948.

Material and Formulation	Rate per 100 Gals. (Lbs.)	Date(s) Sprayed[1]	Number per 100 Shoots		Per Cent Reduction (Borers)
			Infested	Borers	
		Series 1			
DDT (50% W.P.)	4	5/29 and 6/5	60	117	29
DDT (50% W.P.)	4	5/29, 6/5 and 6/12	49	76	60
Untreated			75	164	
		Series 2			
DDT (50% W.P.)	2	6/12	33	36	56
DDT (50% W.P.)	4	6/12	26	26	68
DDD (50% W.P.)	4	6/12	28	29	64
Parathion (25% W.P.)	2.25	6/12	6	6	93
Untreated			50	81	

[1] Series 1, first application 2 days after first moths emerged.
Series 2, treatments made 15 days after first moths emerged.

parathion, DDT and DDD sprays during 1948 are presented in table 4. One application of parathion gave a high degree of control. The performance of parathion was superior to that of chlorinated hydrocarbon insecticides. Both DDT and DDD gave similar control. In a schedule of three applications of 50 per cent, DDT at the 4–100 rate failed to markedly reduce the borer population.

Results of experiments conducted with various schedules of parathion during 1949, 1950, and 1951 are given in table 5. It is evident from the data that parathion is very effective against the borer. One timely application proved to be about as efficient as a schedule of two sprays when the rate of infestation was heavy. The amount of actual parathion was reduced from 6 ounces per 100 gallons in 1949 to 3.6 ounces in 1951. The control with sprays having the low concentration approaches that obtained with larger amounts. However, the indication is that a concentration of 3.6 ounces of actual parathion per 100 gallons is the minimum dosage necessary for commercial control. A spray applied 10 to 13 days after the first moths emerged was effective but the efficiency decreased when the application was delayed for 6 to 8 days later.

Table 5.—Results with several spray schedules of parathion, 1949, 1950 and 1951.

Concentration per 100 Gallons (Lbs.)	Date of Application[1]	Number per 100 Shoots		Per Cent Reduction (Borers)
		Infested	Borers	
	Parathion (25% W.P.) 1949			
1.5	6/7	5	6	94
1.5	6/7 and 6/13	6	6	94
1.5	6/13	11	14	86
Untreated		61	100	
	Parathion (15% W.P. 1950			
2.0	6/20	12	13	90
2.0	6/20 and 6/29	6	6	95
Untreated		72	128	
1.5	6/21	12	12	90
Untreated		71	118	
	Parathion (15% W.P.) 1951			
1.5	6/15	21	28	85
1.5	6/15 and 6/22	21	25	86
1.5	6/22	65	104	44
Untreated		83	185	

[1] 6/7, First application 12 days after first moths emerged and for 6/20, 6/21 and 6/15 the period was 10, 11 and 13 days, respectively.

The data obtained with one and two treatments of several organic phosphorous insecticides for borer control are presented in table 6. The material, ethyl-p-nitrophenyl thiobenzene phosphonate, gave a marked reduction of the borer population in a heavily infested planting. According to the results one application was as effective as two. Against a light infestation a miscible preparation of dimethyl and diethyl-p-nitrophenyl thiophosphate gave promising results. This material and ethyl-p-nitrophenyl thiobenzene phosphonate at the rates used were less efficient than parathion. Malathon and diethoxythiophosphoric acid ester of 4-methyl-7-hydroxy coumarin gave poor control. The organic phosphorous insecticides cause no apparent injury to the foliage and fruit.

LABORATORY EXPERIMENTS.—Tests were conducted in the laboratory to evaluate as ovicides several organic phosphorous insecticides and two verdant type petroleum oils. The large number of eggs required for ovicide tests were obtained by the following procedure: Infested canes were placed in an out-of-doors cage covered with cloth and wire screen. In the cage moths were reared and induced to oviposit on freshly cut one- and two-year old currant canes. Before making these available to the

Table 6.—Results with four organic phosphorous insecticides in spray programs of one and two treatments, 1951.

TREATMENT	DATE(S) SPRAYED[1]	NUMBER PER 100 SHOOTS		PER CENT REDUCTION (BORERS)
		Infested	Borers	
Malathon (25% W.P.)[2] 2 lbs. per 100 gals. water	6/15	53	85	49
	6/15 and 6/22	39	54	68
	6/22	60	119	29
Untreated		77	118	
Ethyl-p-nitrophenyl thionobenzene phosphonate (27% W.P.),[3] 1 lb. per 100 gals. water	6/16	25	30	78
	6/16 and 6/24	24	29	79
	6/24	63	107	23
Untreated		76	139	
Dimethyl and diethyl-p-nitrophenyl thiophosphates (50 mis. liq.),[4] 8 fl. oz. per 100 gals. water	6/16	12	13	76
	6/16 and 6/24	6	6	89
	6/24	22	27	50
Untreated		44	54	
Diethoxythiophosphoric acid ester of 4-methyl-7-hydroxy coumarin (50% mis. liq.),[5] 8 fl. oz. per 100 gals. water	6/16	20	22	53
	6/16 and 6/24	11	12	75
Untreated		35	47	

[1] 6/15, First application 13 days after first moths emerged.
6/16, First application 14 days after first moths emerged.
[2] Test material 4049. American Cyanamid Company.
[3] EPN-300. E. I. duPont de Nemours Company.
[4] Metacide. Geary Chemical Corporation.
[5] Potasan. Geary Chemical Corporation.

moths, most of the leaves and all fruit clusters were removed. Then, four or five canes were arranged in an upright position in a half gallon glass jar partially filled with water. The mouth of the jar was plugged with cotton. Usually six lots of shoots were placed in the cage at one time and this material was exposed to the moths for oviposition for 12 to 36 hour periods.

Prior to applying the treatments all remaining leaves and petioles were clipped from the shoots. The shoots were then cut into sections varying from 4 to 6 inches in length and having from 25 to 125 eggs. The wood sections were impaled on blocks which were similar to those described by Chapman & Avens (1948). Each block with 5 to 7 sections constituted a replicate. In all tests made each treatment was replicated three times. Immediately after the application of treatments the blocks were stored in an open air insectary.

All applications were made with a paint spray nozzle mounted in a fixed position in a spray chamber. The gun was operated with an air pressure of 20 pounds on the liquid and 60 pounds on the spray stream. Only one impaling block was treated at a time. A turntable was used to pass the blocks with the wood sections through the spray stream. The gun and speed of turntable were adjusted so the spray was applied to the point of just runoff.

Table 7.—Efficiency of various concentrations of parathion against eggs in laboratory tests, 1950 and 1951.

PARATHION (15% W.P.) RATE PER 100 GALS.	SERIES 1950			SERIES 1951			PER CENT CONTROL (AVERAGE)
	Total Number Eggs	Per Cent		Total Number Eggs	Per Cent		
		Hatch	Control		Hatch	Control	
2 oz.	1018	31.1	67.3	725	30.0	68.0	67.6
4 oz.	864	4.2	95.6	1458	7.4	92.1	93.9
8 oz.	1070	2.6	97.3	967	1.8	98.1	97.7
12 oz.	—	—	—	1044	0.5	99.6	—
16 oz.	1193	1.9	98.0	1467	0.8	99.1	98.6
32 oz.	882	.5	99.5	—	—	—	—
48 oz.	835	1.6	98.4	—	—	—	—
Untreated	959	95.4	—	1558	93.7		

Attention is called to the relatively low mortality of borer eggs due to natural causes. The hatch of eggs in the untreated checks varied from 93.6 to 96.0 per cent. All results of laboratory tests are expressed as per cent control efficiency which was calculated by means of the Abbott's equation (1).

Parathion and several other organic phosphorous insecticides were evaluated on borer eggs. The data on the ovicidal performance of different concentrations of parathion are presented in table 7. It is evident that this insecticide is very toxic to borer eggs. There is close agreement between the results obtained in two experiments with this material. At the 0.5–100 rate the mortality was above 95 per cent. These data offer in part an explanation as to why a relatively short-lived insecticide gives an outstanding performance against the borer under field conditions. The results with the other insecticides against the eggs are given in table 8. A miscible preparation of dimethyl and diethyl-p-nitrophenyl thiophosphate proved to be quite efficient as an ovicide. This material gave results comparable to those obtained with parathion. As ovicides, ethyl-p-nitrophenyl thiobenzene phosphonate and malathon were inferior to parathion.

Prior to the time that the effectiveness of parathion was determined, verdant petroleum oil sprays were considered as a possible means of control. Preliminary experiments were conducted in the labora-

Table 8.—Efficiency of various concentrations of several organic phosphorous compounds against eggs in laboratory tests, 1951.

Rate per 100 Gallons	Total Number Eggs	Per Cent Hatch	Per Cent Control
Malathon (25% W.P.)[1]			
4 oz.	1105	90.0	5.5
8 oz.	660	77.0	18.4
12 oz.	461	66.8	29.8
16 oz.	741	30.5	67.9
Untreated	2260	95.2	
Ethyl-p-nitrophenyl thionobenzene phosphonate (27% W.P.)[2]			
4 oz.	644	79.3	16.7
8 oz.	543	68.0	28.6
12 oz.	764	45.2	52.5
16 oz.	600	35.7	62.5
Untreated	2260	95.2	
Dimethyl and diethyl-p-nitrophenyl thiophosphates (33.3% liq.)[3]			
3 fl. oz.	495	2.2	97.6
6 fl. oz.	536	0.4	99.6
Untreated	1617	95.0	

[1] American Cyanamid Co.
[2] EPN 300. E. I. duPont de Nemours Co.
[3] Metacide. Geary Chemical Co.

Table 9.—Efficiency of two petroleum oils against the eggs in laboratory tests.

Oils[1]	Per Cent Oil in Spray	Total Number Eggs	Per Cent Hatch	Per Cent Control
A20	0.125	794	99.0	0.0
A20	0.25	977	95.7	0.3
A20	0.75	516	57.6	40.0
A20	1.50	926	3.6	96.3
D20	0.75	696	95.0	1.0
Untreated		1121	96.0	

[1] Two verdant petroleum oils. For specifications see JOUR. ECON. ENT. *36:* 242, 1943.

Table 10.—Results of parathion and DDT residue determinations on currants at harvest, 1947 to 1951, inclusive.

Rate per 100 Gallons (Lbs.)	Date(s) of Application	Last Spray to Harvest: Days	Last Spray to Harvest: Rainfall (inches)	Residue ppm.
	25% Parathion (W.P.)[1]—1948[2,3]			
2.0	5/26, 6/3	39	4.25	0.20
1.0	5/29, 6/3	39	4.25	0.11
2.25	6/12	30	2.66	0.44
	1949[4]			
1.5	6/7	37	2.35	0.03
1.5	6/7, 6/13	30	2.35	0.10
1.5	6/13	30	2.35	0.06
2.25	6/13	30	2.35	0.03
	15% Parathion (W.P.)[1]—1950[4]			
2.0	6/20	22	2.11	0.06
2.0	6/20, 6/29	13	2.02	0.24
1.5	6/21	21	2.11	0.04
1.5	6/21, 6/29	13	2.02	0.15
1.5	6/21	19	2.11	0.30
	15% Parathion (W.P.)[1]—1951[4]			
1.5	6/15	26	4.00	0.01
1.5	6/15, 6/22	19	3.95	0.03
1.5	6/22	19	3.95	0.01
1.0	6/16	25	4.00	0.01
1.0	6/16, 6/24	17	3.24	0.01
	50% DDT (W.P.)—1947[4,5]			
2	6/9	38	3.23	21.1
4	6/9	38	3.23	34.4
2	6/18	9	2.02	20.9
4	6/18	9	2.02	51.3
8	6/18	9	2.02	133.1
	50% DDT (W.P.)—1948[4,5]			
4	6/12	40	3.14	13.6
2	5/29, 6/5	47	5.28	13.0
4	5/29, 6/5	47	5.28	27.8

[1] American Cyanamid Company.
[2] Analyses made by P. R. Averell, American Cyanamid Company.
[3] Reading on blank 0.02 ppm. not subtracted.
[4] Analyses made by A. W. Avens of Division of Food Science and Technology, N. Y. S. Agricultural Experiment Station, Geneva, N. Y.
[5] NNO, 3 oz. per 100 gallons.

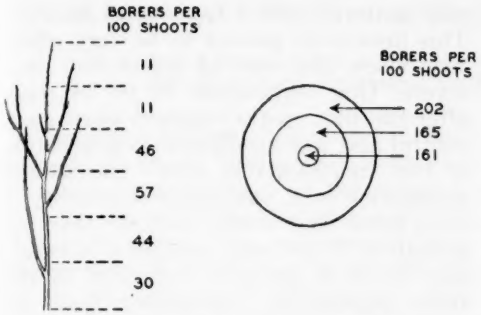

FIG. 1.—Diagram showing distribution of the borer in a cane and in a typical bush.

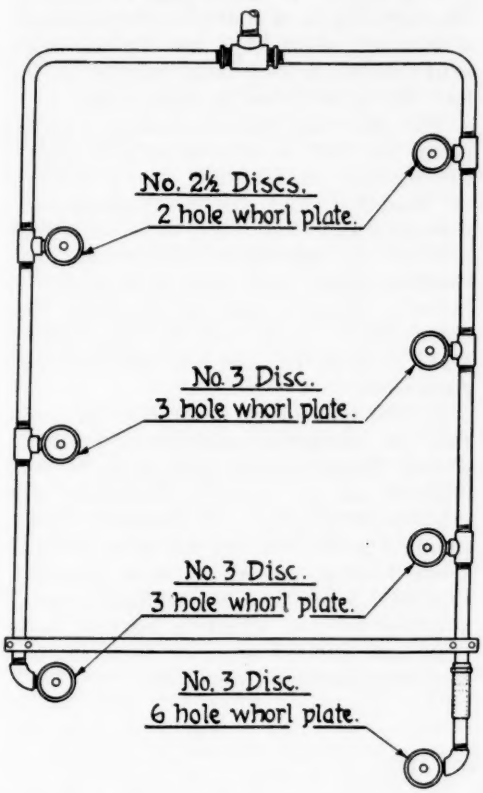

FIG. 2.—Showing spray nozzle arrangement in one side of the spray boom used in experiments.

tory with two verdant type oils against borer eggs. The physical and physiochemical properties of the fractions are given in a paper by Chapman *et al.* (1943) and the codes assigned to the oils by these workers are employed herein.

In the oil sprays blood albumin (2 ounces of actual albumin per 100 gallons) was the emulsifying agent. Emulsification was accomplished by using a hand operated homogenizer. The sprays were prepared in this manner: First the desired amount of oil was added slowly as the emulsifier and water (20 cc.) were being constantly stirred. Then the mixture was pumped through the homogenizer three times. After each operation a small amount of water was added to the emulsion. Finally, as the emulsion was diluted to the desired volume, it was constantly agitated. The method of application of oil sprays was the same as that employed to apply the organic phosphorous insecticides as ovicides.

From the limited data in table 9 it is seen that A20, the highly paraffinic oil, is superior to the naphthenic type. At a concentration of 1.5 gallons the mortality was above 95 per cent. The results are in agreement with those reported by Chapman *et al.* (1943).

SPRAY RESIDUES.—The possibility of the treatments for currant borer control posing a residue problem at harvest was given consideration in this investigation. The sprays are applied after the fruit is set and within a period of 15 to 30 days prior to harvest. Also, the rate of application per acre, 350 gallons, is heavy. Residues on fresh fruit were determined for only parathion schedules. Fruit samples for analyses were picked from bushes located near the center row or rows of the plot. Seven clusters were taken at random from each bush, three across the top and two along each side. The clusters were picked by the stems to avoid any removal of residue by rubbing. All samples were collected in pint cardboard containers. In every season except 1948 four pints of fruit were taken for each treatment. The residue determination was made on a sample which included aliquots from each of the pint lots of fruit. A sample of 300 grams of berries and stems was used in 1947 and 1948. In 1949, 1950, and 1951, the sample weighed 250 grams. To remove the residue, all samples were shaken gently for ten minutes in 500 cc. of benzene. The Averell and Norris method (1948) was employed to determine the parathion residue, and the DDT residue was determined by the Claborn method (1946).

All results of residue determinations are presented in table 10. It is evident from data that harvest residues from parathion treatments as applied for borer

control are very small, 0.30, ppm. or less. During three seasons the greatest residue was 0.42 ppm. and in this instance the treatment was 25 per cent wettable parathion powder at the 2.25–100 rate. The residues from DDT were very high. When a single application of DDT at the 2–100 rate was made 38 days before harvest, the fruit carried a residue of 21.1 ppm.

SUMMARY AND CONCLUSIONS.—Since 1946 the currant borer has been of considerable importance in the principal red currant producing districts of New York. In many plantations the insect was abundant enough to necessitate some remedial measure other than the one usually advised, which was to cut out the infested shoots. The borer overwinters as a nearly mature larva in the currant shoots and pupates in early May. During late May and early June the adults begin to emerge. The eggs are deposited singly and usually on the older canes. At a constant temperature of 80° F. the majority of eggs hatched within 7 to 8 days, whereas under varying temperatures the incubation period of many eggs is 12 to 14 days. After the young borer enters the cane, it burrows in the pith and to some extent in the woody tissue. In heavily infested plantings two and three borers are frequently found in one cane. Since red currants produce most of the fruit on spurs arising from older wood injury to these canes by the borer causes a decrease in yield through a reduction in vigor of shoots.

Five organic phosphorous and two chlorinated hydrocarbon insecticides were evaluated in the form of spray for borer control. Of this group parathion was the only material tested for several seasons. This insecticide proved to be very effective when the rate of infestation was severe. One application 10 to 14 days after the first moths emerged gave good control and was as efficient as a schedule of two treatments in which the second application was made approaximately 7 days later. The results indicate that 1.5 pounds of 15 per cent parathion is necessary for a 95 per cent reduction in the borer population. Laboratory tests revealed that parathion is very toxic to eggs of the borer. At the 0.5–100 rate the control efficiency was better than 95 per cent. The high degree of control with parathion, a relatively short-lived insecticide, under field conditions may be attributed to the fact that it performs as an ovicide.

The other materials that showed promise in the field were ethyl-p-nitrophenyl thiobenzene phosphonate and a mixture of dimethyl and diethyl-p-nitrophenyl thiophosphates but both were somewhat inferior to parathion. Malathon and thiophosphoric acid ester of 4 methyl-7-hydroxy coumarin gave poor control. The chlorinated hydrocarbon insecticides DDT and DDD were less effective than parathion.

In the laboratory a miscible preparation of dimethyl and diethyl-p-nitrophenyl thiophosphates proved to be very efficient as an ovicide. Malathon and ethyl-p-nitrophenyl thiobenzene phosphonate gave poor egg kill at concentrations of one pound or less. At a concentration of 1.5 per cent a paraffinic type of summer oil was effective against borer eggs and proved superior to a fraction high in naphthenic structures.

LITERATURE CITED

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. JOUR. ECON. ENT. **18:** 265–7.

Averell, P. R., and M. V. Norris. 1948. Estimation of small amounts of o,o diethyl o,p-nitrophenyl thiophosphate. Anal. Chem. **20**(8): 753.

Chapman, P. J., G. W. Pearce, and A. W. Avens. 1943. Relation of composition to the efficiency of foliage or summer type petroleum fractions. JOUR. ECON. ENT. **36:** 241–7.

Chapman, P. J., and A. W. Avens. 1948. The toxicology of 4,6 dinitro-o-cresol as an aphid ovicide. JOUR. ECON. ENT. **41:** 190–8.

Claborn, H. V. 1946. Determination of DDT in presence of DDD. Jour. Assoc. Off. Agr. Chem. **29:** 330–7.

Taschenberg, E. F. 1948. Hooded booms for grape spraying. New York (Geneva) Agr. Expt. Sta. Bul. **732:** 1–34.

Bioclimatic Studies of Oriental Fruit Fly in Hawaii[1]

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Bioclimatic cabinet studies were undertaken in Hawaii in 1949 as part of the cooperative investigations on the oriental fruit fly, *Dacus dorsalis* Hendel, outlined by Carter (1950). The purpose of these cabinet studies, which were conducted by the U. S. Bureau of Entomology and Plant Quarantine and the California Agricultural Experiment Station, was to provide information on the effect of temperature and humidity conditions of selected mainland environments on this fly as a basis for predictions on the limits of its distribution and potential pest importance should it ever become established on the mainland. This project has involved the development of bioclimatic cabinets for simulating mainland temperature and humidity conditions, the selection of simulation sites and the procurement of suitable records, the maintenance and manipulation of flies in the cabinets during prolonged experimental periods, and the analysis of large quantities of biological and meteorological data. The studies have not yet been completed, but a report of progress may be of interest at this time because of the threat to mainland agriculture and the concern of regulatory and research agencies over the oriental fruit fly problem.

The use of equipment to simulate climate is not a new idea, but the scope of the Hawaiian studies is undoubtedly without precedent in entomological work. The science of bioclimatics likewise is not a recent development. In 1875 Andrew Delmar Hopkins realized the need for information on how bioclimatic factors affect insect development. In 1905 the U. S. Bureau of Entomology, as it was then designated, initiated a project to study the effect of climate on insect life in our forests (Hopkins 1938). We have come a long way since then, for not only do we study the effect of climate on the insect but we now bring the climate to the insect.

Description of the Cabinets.—The construction of the seven cabinets now in operation in Honolulu was primarily an assembly job, and no new refrigeration or control features were involved, the required performance being achieved and maintained with standard equipment and control devices.

The cabinets are of the walk-in type of sectional knock-down construction, and each has an anteroom to permit entry without influencing the conditions being maintained within. Each cabinet is lined with stainless steel and provided with 36 square feet of working space. On the wall opposite the door is 15 square feet of multiplane glass viewing surface and in the ceiling an additional 4 square feet of glass.

Each cabinet is capable of controlling temperature from −5° to 125° F., with an accuracy of ±1°, on a dry bulb thermometer. In six of the cabinets relative humidity can be controlled through a range of 20 to 95 per cent at temperatures from 35° to 125°. In the seventh cabinet, designed for special studies, it is possible to control relative humidity at subfreezing temperatures. All cabinets have sufficient capacity to raise the temperature 40° and to raise or lower the relative humidity 60 per cent, each within 60 minutes. A blower circulates fresh air through the cabinets at the rate of 20 cubic feet per minute, and the air flow can be regulated by dampers.

An ultraviolet lamp provides light composed of the shorter wave lengths of the solar spectrum, and an infrared lamp provides light of the longer wave lengths. Together these lamps simulate very closely the radiant energy and natural light of the sun. The lamps are controlled with time clocks, which are regulated to take care of the annual declination of the sun at the sites being studied.

Temperature and humidity are controlled by means of cams, which, through tracer points, transmit to the control system the exact conditions required in the cabinets. From mainland hygrothermograph records complete tables of temperature and humidity are computed and tabulated on a 2-hour-interval basis. The data are then transferred to special circu-

[1] Presented at the meeting of the Pacific Slope Branch of the American Association of Economic Entomologists at Santa Barbara, Calif., June 24–26, 1952.

lar charts, which are glued on pasteboard. A jigsaw is used to cut the cam according to the prescribed pattern on the chart. Each week it is necessary to prepare two such cams for each cabinet.

OPERATION OF THE CABINETS.—Maintenance of the proper conditions in the cabinets is not a push-button operation. The cabinets have to be watched closely to make certain that everything is functioning properly and to make the adjustments or corrections necessary for maintaining accurate temperature and humidity control. Consequently someone must be in constant attendance during a run.

Before the bioclimatic cabinet experiments could be started, considerable experimentation was necessary to develop the most practical methods for manipulating the experimental insects. In the procedure that has become standard practice, the flies are contained in a globular screen cage, which permits free air circulation and provides for the maximum amount of light and unobstructed space for the flies. A zipper bottom provides entry for the aspirator used to remove dead flies when making mortality counts, for the introduction and removal of host fruits, for the replenishment of the food supply, and for the restocking of flies. The globular cages are suspended from a bicycle-wheel hanger, which is slowly rotated by a jet of air blowing on specially constructed fins to eliminate any effects of positional differences.

The adult flies in the cages have access to two types of diet. The synthetic materials soy bean hydrolysate and yeast hydrolysate provide nutrients essential for the development of sexual maturity and for maximum fertility, productivity, and longevity.[1] Fresh guava fruits are also available to provide the flies with a natural food for a balanced diet. There is always water present as well as a substrate for oviposition. Papaya is generally used for the latter, because it is abundant throughout the year and it is an excellent medium for oviposition and subsequent larval development.

After it has been removed from a cage, each papaya fruit that has been exposed to the flies is placed on sand in the bottom of a combination holding box and cage. When the larvae are full grown, they leave the decaying fruit and burrow into the sand, where they pupate. After emerging from the puparia, the flies ascend into the upper portion of the container, where they may be immobilized with carbon dioxide, counted and sexed and then returned to another globular cage reserved for progeny stocks.

In each climate-simulation study information is obtained on the length of the various stages and the preoviposition period, oviposition activity, adult longevity, the degree of fruit infestation, the length of the pre-imaginal period, the number of progeny, and the development of subsequent generations. Values determined under the optimum conditions of 80° F. and 60 to 70 per cent relative humidity in a constant-temperature cabinet are used as standards of comparison in interpreting results. Under these conditions the length of the egg stage of the oriental fruit fly is about 36 hours, the larval stage 8 days, the pupal stage 10 days, the preoviposition period 11 days, and the life span of the adults about 35 days. The entire life cycle under optimum conditions may be completed in about 30 days.

PRELIMINARY STUDIES.—Temperature and humidity conditions representative of the climates of Oceanside, Fresno, and Riverside, Calif.; Charleston, S. C.; Fort Pierce, Fla.; and Vincennes, Ind., were simulated in the initial cabinet studies with the oriental fruit fly. The simulation runs were started with early-spring conditions and continued for an entire year. Temperature and humidity patterns recorded during the outdoor biological studies on Maui were simulated in a seventh cabinet to provide a check on the reliability of the cabinet results.

The biological findings from one year of continuous cabinet operations are both interesting and enlightening. In confirmation of the results of extensive field studies[2] it was found that the lowest average temperature at which the immature stages of the oriental fruit fly can develop is about 57° F., that temperatures above 70° are necessary for the fly to attain sexual maturity without the preoviposition period become unduly extended, and that twilight temperatures lower than 60° may limit the mating of the oriental

[1] Studies conducted by the California Agricultural Experiment Station.

[2] Conducted by K. L. Maehler and C. J. Davis, U. S. Bureau of Entomology and Plant Quarantine.

fruit fly, which copulates only at dusk. At an average temperature of 57° the total period that the flies were in the immature stages was more than 60 days. The range of mean temperature at which the oriental fruit fly was able to reproduce efficiently was 65° to 80°.

In the climates simulated there was a marked effect of temperature on the rate of growth of the pre-imaginal stages. In cool weather, the rate of growth was much slower than when the temperatures were higher. When temperatures seldom reached 70° F. and the average temperature was 60° or lower, development was greatly inhibited.

In general, there was a good correlation between the length of the favorable reproductive periods and the number of progeny. The smallest number of first-generation progeny were obtained in the Riverside cabinet. The Fresno cabinet produced a few more, but the number of individuals in the second generation was lowest, probably because of the daily temperature extremes, often lethal which occurred during the summer months. On one occasion 3000 flies were killed within a few minutes when the temperature exceeded 100° F., and during hotter periods the emergence of adults was greatly reduced.

To a less degree similar conditions affected progeny in the Riverside cabinet in a comparable manner. The Oceanside cabinet produced the most progeny of any of the California cabinets, but the greatest population build-up occurred during the summer months. No progeny were recovered in the Oceanside, Riverside, and Fresno cabinets after the onset of winter temperatures below those required for pre-imaginal development. The Charleston cabinet produced high first- and second-generation populations during favorable weather but in this cabinet net also production declined to zero with the arrival of winter. The oriental fruit fly was able to develop in the Vincennes cabinet only under climates of late spring summer, and early fall.

The climate of Fort Pierce, Fla., was unquestionably the best for the development of the oriental fruit fly. In the Fort Pierce cabinet conditions were optimal for pre-imaginal growth and progeny returns were high during almost the entire simulation period. Year-round reproduction was maintained, a fourth generation developing in the cabinet late in the winter. A total of almost 30,000 flies, approximately one-third of the progeny from all cabinets, were recovered during the complete annual climatic cycle.

Additional simulation runs and special studies that will provide information on specific temperature and humidity combinations and patterns of fluctuation that adversely affect fruit fly development, or may have a lethal effect on established infestations are now in progress. The melon fly, *Dacus cucurbitae* Coq., and the Mediterranean fruit fly, *Ceratitus capitata* (Wied.), both of which are a potential threat to mainland agriculture, are also included in these new studies.

LITERATURE CITED

Carter, Walter. 1950. The oriental fruit fly: Progress on research. JOUR. ECON. ENT. **43**: 677–83.

Hopkins, Andrew Delmar. 1938. Bioclimatics. A science of life and climate relations. U. S. Dept. Agr. Misc. Pub. No. **280.**

Fly Control with a New Bait Application Method

Robert K. Thompson, Arthur A. Whipp, Donald L. Davis and Edward G. Batte[1]

This study has been directed toward finding a practical solution to the widely reported insecticide resistance of the housefly, *Musca domestica* (Linn.). These efforts have been directed particularly to fly control in dairy barns or in similar situations. Early in the course of the study it was recognized that fly control in dairy barns has been ineffective due not only to insecticide resistance of flies but also to the lack of proper equipment for application. The difficulty in using such equipment as the knapsack sprayer has resulted in many farmers ignoring the fly problem so far as possible. Another alternative has been to hire custom sprayers but in this case the cost of the treatment has prevented many farmers from using this means of control.

Further, with much doubt existing concerning the future of any new residual-type treatment for fly control, this study was initiated to evaluate poison baits as a means of fly control. Using lindane as the toxicant, various methods of applying a poison bait were tried, such as using knapsack sprayers, garden hose spray attachments, power sprayers, bucket pumps, garden watering cans, and pans. Of all these methods the common garden sprinkling can proved to be most effective and satisfactory. Such equipment is readily available to all people and obviates the possibility of poor fly control due to improper operation of the equipment.

Method of Application.—The toxicant plus a bait substance, such as corn syrup, is added to approximately 10 quarts of water in a sprinkling can. By experience it has been found that the best places to apply the material are on the floor, in the aisles, along the platforms, behind the gutters, in the milk room, and feed room of the dairy barns. Generally best results are obtained when applications are made in a wet strip rather than sprinkling lightly over the entire area.

Application is made immediately after mixing, preferably to clean floor surfaces, since manure, straw, sawdust or dirt absorbs the liquid so that it is not as available or attractive to the flies. The bait is applied generally in those areas most frequented by flies. As a routine control practice it was found best to make applications following the morning clean-up in the dairy though in periods of cool weather applications later in the day when the flies are more active would give better results. Where good floor surface is not available or where the wet residue would be un-desirable on the floor, it was found that treating burlap sacks provided very satisfactory control. The sacks are placed near doorways or other places most frequented by flies.

Lindane Bait.—The first test work was conducted in 1951 using a lindane bait in several dairies (Fig. 1). The total fly count on any particular day was determined by counting the number of flies on several structures within the barn such as on stanchions, rails or posts. Subsequent counts were always made on these same structures and an attempt was made to make counts at approximately the same time each day. Fair control was obtained in two dairies and very good control obtained in another dairy where the lindane bait was applied to the floor three times weekly. At the Clark and F. Peacock Dairies a 0.3 per cent lindane bait was used, however, at Willets' a 0.6 per cent lindane bait was used, though only one-half as much diluted bait was applied at Willets' on an equal area basis. The success of the method of application was apparent when the best results were obtained at the Willits Dairy, in which case it is known that the fly population is highly resistant to the lindane, at least when applied as residual-type application. Here, with three floor applications, the fly count dropped from somewhat over 300 to less than 25. When tried in other areas where lindane resistance was even more pronounced, adequate control was not obtained.

Lindane Plus TEPP Bait.—Further tests were made using a combination of lindane and TEPP. During the winter of 1951–52, tests were continued in the Miami area and later, as the fly season approached, in Louisiana, Texas, North

[1] Research and Development Dept., California Spray-Chemical Corp.

The authors wish to acknowledge confirming experimenta work conducted by Benson F. Quisenberry, John E. Moore, Richard D. Wessel and Frank D. Johanson, also of this organization.

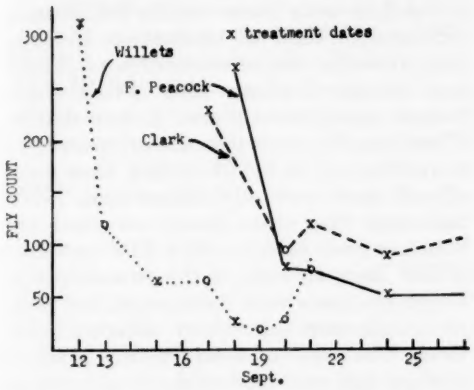

FIG. 1.—1951 Tests with lindane bait applied to floor of dairy barns with sprinkling can.

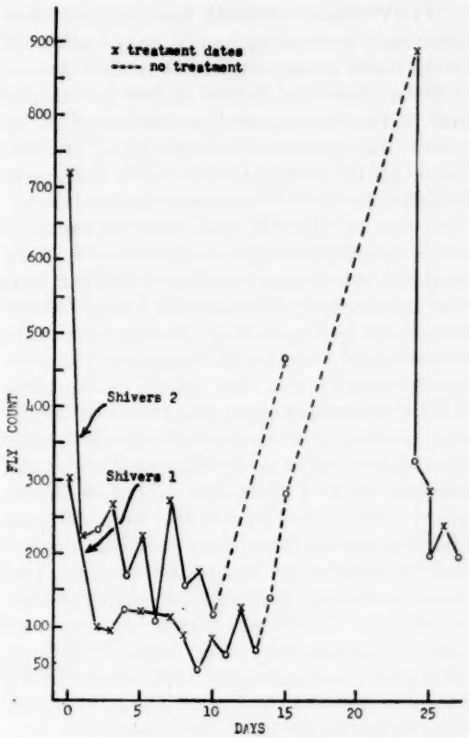

FIG. 2.—Housefly population trend with lindane-TEPP[1] bait applied to floor of dairy barns with sprinkling can.

Carolina, New Jersey, New York and Connecticut. It was found that a dosage of 0.15 per cent lindane plus 0.06 per cent TEPP, mixed with syrup or other feeding attractant and sprinkled on the floor of the barn, gave a very rapid kill of the flies present and, after the initial population had been reduced, or when it was primarily one of migrant flies, a treatment every 2 to 4 days was sufficient for satisfactory fly control. A special emulsifiable formulation, called *HL 636* (10.7 per cent lindane plus 4.3 per cent TEPP), was prepared so that 0.25 pint of this formulation added to 2.5 gallons of water, would give the desired concentration of 0.15 per cent lindane and 0.06 per cent TEPP. First, 4 to 8 ounces of an attractant such as syrup, molasses, dried milk, whey or calf starter is added to the can of water, the *HL 636* added, then applied immediately. Though extensive tests have not been run on different baits, the most consistent results have been obtained using corn syrup. Results of a few tests using *HL 636* for fly control are illustrated in figures 2 and 3. Although tests have been conducted in more than 30 dairies, only results of sufficient number are shown here to illustrate the effectiveness of the method. Typical of results obtained at many dairies are those obtained at the Shivers Dairy in Test No. 1. Starting early in the season, a moderate fly population was brought under control in a very short time. Treatments were then stopped and after about 10 days without treatment the population had increased to very serious proportions. At this time treatments of *HL 636* lindane-TEPP bait, were again started and the population again was brought under control very rapidly. The greater fluctuation in fly counts for different tests is due to the very heavy breeding at the Shivers Dairy and the unsanitary condition of the barn. It was found that in a situation such as this, where the floors were littered with much soil, it was necessary to use two sprinkling cans full of the toxicant bait to obtain control comparable with that obtained in other dairies using only one sprinkling can full, or 10 quarts of bait, to cover the entire floor area which, for an average-sized dairy, 2000 to 3000 sq. ft. of floor space would be the usual area. The very low fly counts obtained at the Peacock Dairy (Fig. 3) and the lack of fly build-up on cessation of treatments at the end of this test is due to the lack of any extensive breeding around the dairy.

[1] *HL 636*, California Spray-Chemical Corporation.
[2] Low counts on these days due to cold weather resulting in flies resting outside barns.

TEPP BAIT.—TEPP bait, at very low dilutions, proved to be not only highly effective and a very rapid (20 to 30 seconds) killer of flies that fed on it, but it was also one of the few liquid insecticides of many tried that did not repel the flies. The lindane-TEPP fromulation, *HL 636*, also is not repellent. However, due to the hydrolysis of TEPP, the effectiveness of such sprinkled baits is short-lived. Subsequent investigations have shown that for satisfactory fly control, using TEPP alone, daily treatments, or in some cases twice daily, might be required for adequate protection. In each case where TEPP was used alone the trend of the fly population was definitely upward, and then when followed by the combination of lindane plus TEPP, the trend is downward (Fig. 4). These tests were all conducted with approximately a 2-day interval of treatment inasmuch as that had been found to be satisfactory using the lindane plus TEPP bait which in some cases proved satisfactory even for 3 or 4 days. However, we see here that with TEPP alone a 2-day interval will not keep the flies under control.

Further tests were conducted using a different method of evaluation to compare directly the effectiveness of TEPP bait versus lindane plus TEPP bait, Paired panels were placed in two dairies. These panels consisted of burlap-covered wood frames 18 by 24 inches. One panel of each pair received 0.06 per cent TEPP bait and the other panel received the 0.15 per cent lindane plus 0.06 per cent TEPP bait. In each of the two dairies in which the tests were conducted, five pairs of panels were placed at different locations. The count of dead flies was made at various intervals following treatment on each panel. A plus count was given the panel on which was found the greatest number of dead flies. The combined results of these tests are shown in table 1. The total combined counts gave 32 plus counts for TEPP against 98 plus counts for lindane plus TEPP (*HL 636*). It should be noted, however, that for the first counts following treatment, that is, at the 4 to 10 hour interval, there was very little difference between the number of plus counts for either treatment. For counts made at later times, the difference was highly in favor of the lindane

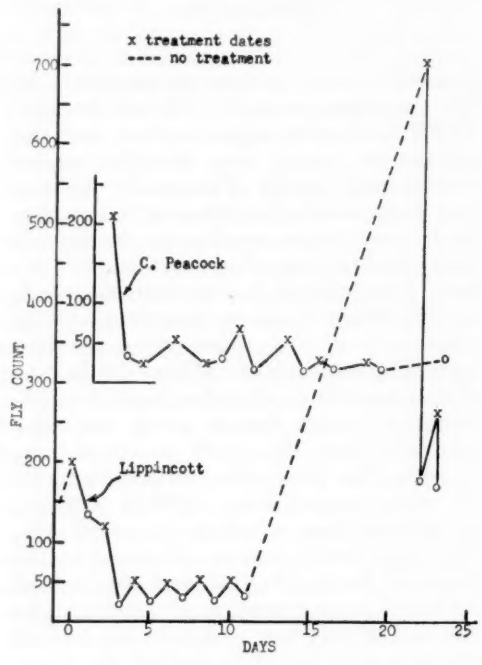

FIG. 3.—Housefly population trend with lindane-TEPP[1] bait applied to floor of dairy barns with sprinkling can.

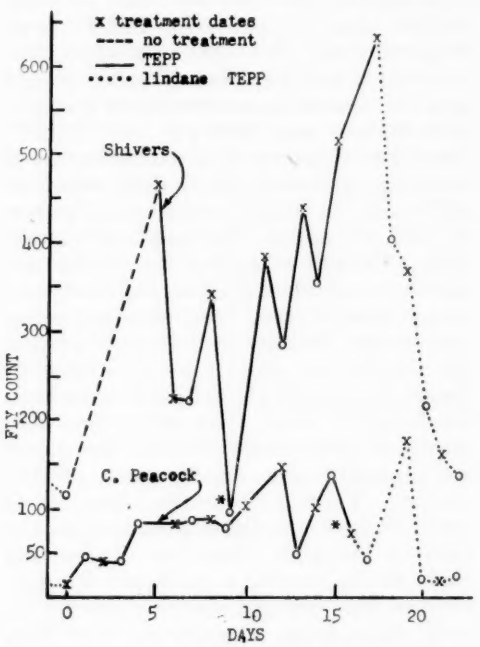

FIG. 4.—Housefly population trend with TEPP bait applied to floor of dairy barns with sprinkling can.

plus TEPP. This would normally be expected inasmuch as the TEPP hydrolyzes rapidly and there would be very little present after the first counts or by the time of the second count, which was made 1 day after treatment. A large number of flies were killed, however, 1 and 2 days after treatment, indicating that the lindane was a very effective part of the formulation. This also was noticed in many of the practical dairy trials where, for the first few hours after treatment, nearly all the flies seen dying were showing symptoms of TEPP poisoning. However, later especially the following day and up to 5 days following treatment, flies showing lindane symptoms would be found.

HORNFLY CONTROL.—During the early work with lindane-TEPP bait (*HL 636*) for housefly control, it was noted that at several dairies hornflies, *Haematobia stimulans* (Meigan), disappeared after a few applications. In all instances, the material had been applied on the floor as wet strip in various locations of the barn including the area between the stanchion and gutter, extending the length of the milking line. When the cows were brought in for milking, they stood on the floor that had been treated. With the temperatures that normally prevail during the fly season, there was apparently enough volatilization of lindane to give hornfly control.

To achieve hornfly control with *HL 636*, it appears necessary that the cows remain in the barn at least an hour. In four dairies using this method, the average count before the application of *HL 636* was 35.5 hornflies per cow. After 2 to 4 applications the average count was less than 1 fly per cow. The results for the individual dairies are shown in table 2. There was no apparent difference between the results when the material was applied soon after the morning milking, or, in the early afternoon. Nehlsen's is an old dairy barn which had concrete floors only where the cows stood while in stanchions and the diluted *HL 636* was applied only in this area. There was an average of 20 horn flies per cow on the pre-count and, after 3 consectuvie daily applications, there were no hornflies observed on any cow. Equally effective hornfly control was obtained at the other dairies.

The application of 0.06 per cent TEPP as a poison bait gave no appreciable reduction in hornfly population after 3 and 2 consecutive daily applications in two dairies. Results of these tests are also shown in table 2. Obviously, TEPP alone, applied to the floor as a bait, does not affect the hornflies. At these two dairies, as seen in table 2, the hornfly count remained nearly the same following 2 or 3 daily applications of 0.06 per cent TEPP bait.

Some dairies use the Pen-Stable method or other rapid milking procedures where the cows would remain on the treated floor for a short time. Hornflies were not controlled in one diary where *HL 636* was applied to the floor of a milking parlor and the cows remained on this floor for only 15 to 20 minutes.

EVALUATION OF HAZARD.—To determine the toxicity of *HL 636* to animals, dairy calves were sprayed with TEPP alone and in combination with lindane.

Table 1.—Results of tests with TEPP and lindane-TEPP on paired burlap panels.

LOCATION	TIME OF FLY COUNT AFTER APPLICATION	PLUS COUNTS TEPP	PLUS COUNTS LINDANE +TEPP
Willets 5 applications	4–10 hrs.	3	11
	22–30 hrs.	1	17
	44–50+ hrs.	3	19
	All Times	7	47
Lippincott 6 applications[1]	4–10 hrs.	10	8
	22–30 hrs.	7	25
	44–50+ hrs.	8	18
	All Times	25	51
Combined	4–10 hrs.	13	19
	22–30 hrs.	8	42
	44–50+ hrs.	11	37
	All Times	32	98

[1] First three applications on the TEPP only panels at Lippincott's made at 2× concentration.

Table 2.—Hornfly control with lindane-TEPP bait applied to floor of dairy barns with sprinkling can.

LOCATION	AVERAGE HORNFLIES PER COW				
	Precount	1 day	2 days	3 days	4 days
Homstead	40.0[1]	0.1	1	—	1.0
Nehlsen	20.0[1]	1	1	0.0	
Rudderow[3]	61.5[1]	1	1	3.25	1
Jonesdale	23.4[1]	10.2[1]	1	—	0.0
Homestead[2]	37[2]	2	40		
Jonesdale[2]	60[2]	68[2]	62[2]	50	

[1] Lindane-TEPP applied these days.
[2] TEPP only.
[3] Rudderow, 5 days, no flies.

After three consecutive daily sprayings of 4 quarts of 0.03 per cent TEPP to a 3-day Guernsey bull calf, no symptoms of poisoning were noticed. Two consecutive daily sprayings of 4 quarts of 0.06 per cent TEPP did not produce poisoning symptoms in a 3-day Jersey bull calf. One spraying of 4 quarts of 0.25 per cent TEPP was fatal to a 3-day Jersey bull calf. Two applications on successive days of 0.5 pint of a mixture of 0.3 per cent lindane plus 0.06 per cent TEPP was not toxic to a 3-day Jersey calf. The application of 0.75 pint of the same combination was not toxic to a 3-day Jersey bull calf.

Because of the ever-present pets in dairies, it was decided to check the toxicity of *HL 636* to cats. Four half-grown cats were confined on 3 consecutive days on a concrete floor treated daily to run-off with *HL 636* at 25 cc. per sq. ft. (diluted to give 0.15 per cent lindane plus 5.06 per cent TEPP). No symptoms of TEPP or lindane poisoning were observed. The application of *HL 636* to a shaved area on a lactating cat at the rate of 10 mgm. TEPP per kgm. produced symptoms of phosphate insecticide poisoning. From the observed symptoms it appeared that the lindane part of the formulation contributed little or nothing to the toxicity. In many of the barns treated with *HL 636* there have been dogs, cats, ducks and chickens. There have been no symptoms of insecticide poisoning observed in any animals at these dairies.

It has been found that the primary hazard lies in handling the concentrated material (*HL 636*) and not in handling or using the diluted bait solution. It has been reported by Lehman (1948) that the mean lethal dose of TEPP by oral administration is 2 mg./kg. and estimated that the quantity dangerous from a single skin application to be 10 mg. TEPP/kg. On this basis the following table indicates the quantity of diluted solution necessary to be dangerous to the various animals and the square feet of floor space from which all the material when sprinkled to run off (25 cc./sq. ft.) must be absorbed completely to give the amount estimated to be dangerous.

It would appear from this that when *HL 636*, lindane-TEPP bait, is handled with reasonable care that it can be used for fly control in dairy barns and other similar situations with no undue hazard to the operator or to animals and people frequenting or working in the buildings.

Table 3.—Amount dilute lindane-TEPP bait estimated dangerous.

	Pounds	Oral	Single Dermal	Square Feet Covered
Man	154	233.00 cc.	1166.0 cc.	46.6
Child	66	100.00 cc.	500.0 cc.	20.0
Cat	5	7.56 cc.	37.8 cc.	1.5
Kitten	2.2	3.30 cc.	16.6 cc.	.66
Calf	220	333.00 cc.	1665.0 cc.	66.6
Cow	660	999.00 cc.	4995.0 cc.	199.8
Dog	17.6	26.60 cc.	133.0 cc.	5.3

MILK CONTAMINATION STUDIES.—Samples of milk were taken from several barns that were to be treated with lindane plus TEPP. The barns were treated in the normal manner and milk samples taken on the morning following treatment and on subsequent days and then analyzed. No lindane or TEPP was found in milk samples taken from cows in the treated barns.

SUMMARY.—Of several methods of applying poison baits for house fly control, the most effective and satisfactory was found to be use of a garden sprinkling can. By use of a sprinkling can the diluted toxicant plus bait is applied to the floor of dairy barns in irregular wet strips, but particularly in those areas where flies congregate. Effective fly control has been obtained in many dairies and otherwise in similar situations with a bait containing 0.15 per cent lindane plus 0.06 per cent TEPP where applications are made at 2 to 3 day intervals. Baits containing 0.06 per cent TEPP only are ineffective when used every 2 days, though large numbers of flies may be killed the day of treatment.

The floor treatment with the lindane plus TEPP bait also controls hornflies when cows remain on the treated floor about 1 hour at each milking. Where rapid milking procedures are used and cows remained in the barn only 15 to 20 minutes hornfly control was inadequate. Also, when TEPP only was used in the bait no hornfly control was obtained.

The use hazards of a lindane-TEPP bait are evaluated. It appears that the primary hazard lies in handling the concentrated material (10.7 per cent lindane plus 4.3 per cent TEPP), and not in handling or using the diluted bait solu-

tion. Applications to young dairy calves at use dilution did not produce any symptoms of poisoning and small animals in walking on treated surfaces have not developed symptoms, even when confined thereon.

Milk samples from treated dairies were analyzed and no lindane found in the milk.

LITERATURE CITED

Lehman, A. J. 1948. The Toxicology of the newer agricultural chemicals. Bul. Assn. Food and Drug Officials of the U. S. 12: 82–89.

An Urban Fly Control Campaign[1]

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The community fly control problem is not one of recent origin but lately the public has become increasingly aware of flies as possible vectors of human diseases. Although controlling flies is basically a matter of good sanitation, chemical control measures are usually employed to compensate for inadequate sanitation.

Fly control is a vital factor in maintaining health in a community. This has been pointed out by Watt and Lindsay (1948) in connection with diarrheal disease control. Paul *et al.* (1941), Sabin & Ward (1941), Ward *et al.* (1945), Melnick *et al.* (1947), Francis *et al.* (1948), Melnick (1949), and Herms (1950), reported the virus causing poliomyelitis present in flies. Publications by Bishopp (1915) and James (1947) indicate there are several species of flies causing myiasis in man and animals. In addition to being hazardous to health, flies are, of course, extremely annoying.

The problem of controlling flies probably has existed as long as man himself and has in the past involved such devices as baited traps, poisoning, and sticky fly papers. The use of cloth, plastic, and wire screening has also been quite effective in keeping flies out of buildings. The most recent approach to controlling flies has consisted of a combination of good sanitation and the applications of insecticides with long-lasting residual properties.

Nearly a half century ago, a Kansas health officer, Dr. Samuel J. Crumbine, conducted one of the first community fly control programs in the nation (Hodgden 1950). Doctor Crumbine urged the cleaning up of insanitary conditions and the use of a new invention, the fly swatter. In 1909–10, W. B. Herms conducted a successful community-wide fly control campaign in Berkeley, California. There was apparently a decline in campaigns of this type for some time thereafter (Herms 1950). Since the advent of DDT and other insecticides of similar properties and increasing interest in the possibility of suppressing poliomyelitis through fly control, community fly control programs again have become popular (Schoof *et al.* 1951).

The fly control campaign reported here occurred during the summer of 1950 in the city of Manhattan, Kansas. The purpose of the campaign was basically threefold: (1) to evaluate the U. S. Public Health Service methods and procedures for making fly population surveys, (2) to obtain data on the species of flies and their prevalence among the fly population in the area, and (3) to obtain fly control in the community by a combination of improved sanitation and application of a residual insecticide.

PROCEDURE.—The various aspects of this fly control program were carried out in the city of Manhattan, Kansas, a community located in the east-central region of Kansas, at the confluence of the Big Blue and Kansas rivers, and with a population of approximately 19,000. A preliminary survey of the city was made during the latter part of May, 1950, to determine sanitary conditions and the locations of potential fly breeding areas. On the basis of this survey, the city was divided into three sections, each consisting of different sanitary conditions (U. S.

[1] Contribution No. 600 Department of Entomology; part of a thesis submitted by C. C. Burkhardt in partial fulfillment of the requirements for the degree Master of Science in Entomology. This work was conducted as a municipal fly control program coordinated with the Riley County, Kansas, Board of Health and the Kansas State Board of Health. The work was supported in part by funds from these agencies.

[2] Instructor and associate professor respectively in the Department of Entomology, Kansas State College, Manhattan, Kansas.

Public Health Service 1950). Each of these sections was in turn broken down into smaller evaluative units, using the homogeneity of the blocks in the section as the basic criterion (Fig. 1). Section I, comprising the principal business districts, consisted of four evaluative units, designated A, B, C, and D, lying in the downtown business district, and a fifth unit, designated by the letter E, which was a small business district adjacent to the campus of Kansas State College. Section II, comprising the lower class residential districts, was divided into three units, designated A, B, and C. Section III, consisting of the major residential area in the city, was divided into 13 units, designated by the letters A through M. Every block of each evaluative unit was assigned a number for convenience in recording data.[3] A total of 344 city blocks was included in the survey and subsequent divisions. The sections designated I, II, and III were 15, 10, and 75 per cent, respectively, of the total city area.

The personnel participating in the fly control program consisted of a city fly-control committee, a supervisor in charge of the program,[4] a spraying crew, and the city sanitarian.

The fly grill method of sampling the fly population throughout the city (Scudder 1947) was used in a manner similar to that reported by Baker & Schwartz (1947) and Smith (1948). Standardized forms, consisting of fly grill cards and charts, were used for recording the fly population sampling data.[5] Data such as block numbers, species and numbers of flies, attractants, and climatic conditions for each grill reading were recorded on the fly grill cards. Usually, fly grill counts were taken at 10 to 12 different places in each block, no two places being less than 10 feet apart. Only the five highest grill readings in each block were recorded (Coffey & Schoof 1949). The number of flies was not only counted, but a record was made of the genera and species of flies whenever possible. The most frequently encountered flies were the house fly, *Musca domestica* L., green-bottle flies of the genus *Phaenicia* (=*Lucilia*), the black blow fly, *Phormia regina*, and flesh flies of the genus *Sarcophaga*. Other flies encountered only occasionally were species of *Callitroga*, including the American screw-worm fly, *C. americana* (C. & P.), the stable fly, *Stomoxys calcitrans* (L.), and flies of the genus *Muscina*.

Weekly surveys of the fly population in the city were made on the basis of the "station method" by which certain blocks were selected for surveying within each evaluative unit (*e.g.* I-A in figure 1) and designated as follows:[6] (1) "Fixed block station," that block within the unit which had the greatest fly breeding potential. (2) "Random block station," a block selected at random within the unit. (3) "Dump block station," a third block associated with an extremely high fly breeding potential and atypical in make-up from the other blocks, *e.g.* a block containing dairies, meat packing concerns, and exposed garbage. Following this plan, an average of 16 per cent of the total number of city blocks was sampled weekly. In addition to the weekly surveys pretreatment (before spraying) and post-treatment (after spraying) surveys were conducted to sample the adult fly population immediately before and after applying the insecticide. These surveys were made in a manner similar to that used in making the weekly surveys, and provided a measure of the effectiveness of the insecticidal treatment. Insanitary conditions which provided material for fly breeding were reported to the city sanitarian for correction, if possible.

The average number of flies per block, used as a standard, was selected on a somewhat empirical basis. When a block average was in excess of this standard, chemical control measures were applied to the area. During the early part of the fly control program, an average grill count of three flies per block was used as the standard, but later in the program the standard was increased to an average grill count of five flies per block.

A 300-gallon hydraulic sprayer provided with two spray guns was employed to carry out the necessary spraying operations. Each spray gun consisted of an 18-inch wand with a hand-operated, trigger

[3] The selection of evaluative units was aided by the suggestions of Dr. H. F. Schoof of the Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

[4] The senior author.

[5] Obtained from the Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

[6] Personal communication from Dr. H. F. Schoof, Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia, entitled "Entomological procedures for evaluating community fly control programs," May 2, 1950. Since this paper was written, the authors have learned that Dr. Schoof has a manuscript in preparation dealing with the subject entitled "Survey and Appraisal Methods for Community Fly Control Programs."

type, cut-off valve in the base. The nozzle at the tip of the wand dispersed a flat, fan-shaped pattern of spray material.[7] A 2.6 per cent water emulsion of DDT, prepared from a 25 per cent emulsifiable concentrate, was sprayed on exposed garbage, garbage cans and racks, back doors and walls of buildings along alleyways at a rate of approximately one gallon of spray per 1000 square feet of area (equal to about 100 milligrams of DDT per square foot of area). Application was made at an operating pressure of about 100 pounds per square inch. The effectiveness of the control measures and the intervals between sprayings were determined by the survey methods described above.

Fly population surveys similar to those conducted at Manhattan were conducted by the U. S. Public Health Service at Lawrence, as a routine part of the federal cooperative fly control program at Topeka. The city of Lawrence has a slightly greater populace than Manhattan and was located approximately 90 miles east of Manhattan in the Kansas River valley. No chemical control measures were employed in Lawrence, therefore the fly population data for this city were used as a basis of comparison to evaluate the control of flies obtained in Manhattan.[8]

For interpretation of the data, a weighted, over-all comparison of the grill averages for both cities was computed from the data for Manhattan and Lawrence. The weighted grill averages were derived by adding the products of the sectional grill averages times the percentage of city blocks in each section, and dividing by 100. The sectional grill averages were calculated from the fixed and random block station grill counts for each section. In this manner, weighted weekly over-all city grill averages were computed for all flies (Fig. 2) and for *Musca domestica* (Fig. 3) and *Phaenicia* spp. (Fig. 4).

RESULTS.—Using the methods described above it has been possible to determine the fly population within the city limits of Manhattan, during the summer months of June, July, and August, 1950. Weighted weekly over-all city grill averages, computed from the data for both Manhattan and Lawrence during this period, are presented graphically in Figure 2. It is apparent that Lawrence had a consistently higher fly population throughout the summer than Manhattan. The lowest weighted over-all city grill average for Lawrence was 2.8 which was not much lower than the highest weighted over-all city grill average (3.6) for Manhattan, during the same period of time. Fly population trends were similar in the two cities for weeks 23 to 29 (Fig. 2). Non-conformance of trends after week 29, showed a decline in fly prevalence in Manhattan as compared with the control in Lawrence and is indicative of effective control.

The methods used in making these studies provided data for a comparison of certain genera and species of flies in the two cities. Although the flies were identified macroscopically only as they appeared on the fly grill it is believed the determinations were quite accurate within the categories for which specific data were recorded. The most abundant fly species in both cities during the period of this experiment was the house fly. The second most abundant group of flies were the greenbottle flies of the genus *Phaenicia* (= *Lucilia*). The weekly weighted over-all grill averages for *Musca domestica* and *Phaenicia* spp. in the two cities for the period May 21 to August 19, 1950. The relative abundance of *Phormia regina* and *Sarcophaga* spp. followed the same general trends in the two cities with the highest fly counts appearing early in the season (June). Population trends of *M. domestica* and *Phaenicia* spp. were also similar in both cities except that population peaks of these species were reached much later in the season (weeks 29 to 32) than for the two former species. A comparison of the percentages of these and other species of flies encountered in the two cities during the summer of 1950 is summarized in table 1. Those species of flies which were recorded on the fly grill cards, but which were too few in numbers to record separately in table 1, have been listed previously under procedure.

A striking feature of the data in table 1 is the similarity of percentages of the various species of flies in Manhattan and Lawrence during the summer, although an attempt was made to suppress or control the number of flies in Manhattan.

[7] A nozzle such as Spraying Systems Co., Chicago, Ill., 1/4T5003.

[8] The data from Lawrence, Kansas were obtained through the courtesy of the Communicable Disease Center, U. S. Public Health Service, Atlanta Georgia.

Table 1.—A comparison of the percentages of various fly species occurring in Manhattan and Lawrence, Kansas, during the months of June, July, and August, 1950, as determined by the Scudder (1947) fly grill survey method.

Fly Species	City	
	Manhattan	Lawrence
	(%)	(%)
Musca domestica	58.2	54.4
Phaenicia (=*Lucilia*) spp.	28.0	31.5
Phormia regina	6.3	6.4
Sarcophaga spp.	3.3	1.2
Others[1]	4.2	6.5

[1] See Procedure for a listing of some of the species included here.

The nearness of the two cities to one another and the almost identical temperatures and precipitation prevailing during the interval of this study (Table 3) may help explain this resemblance in data.

Because of the similarity of percentages of the various species of flies and the almost identical temperatures and precipitation prevailing in Manhattan and Lawrence during the summer of 1950, the weighted weekly over-all city grill averages were used as the basis for determining the fly control obtained in Manhattan. An average of approximately 70 per cent control of flies was obtained in Manhattan during the summer by using this method of measurement.

During the month of June, when chemical control methods were most extensively employed in Manhattan, a pretreatment survey of 272 blocks (equivalent to about 80 per cent of the total in the city) resulted in an over-all city grill average of 3.6 flies per block. Of the 272 blocks surveyed, 201 blocks were sprayed with the DDT water emulsion and a posttreatment survey made. The posttreatment over-all city grill average was 0.9 fly per block indicating a 75 per cent city-wide reduction in grill indices which was largely due to the effects of the DDT. The posttreatment data showed further that the highest average numbers of flies were found in the business districts (Fig. 1, Section I, units A through E), followed closely by the high numbers of flies in the lower class residential districts (Fig. 1, Section II, units A, B, and C).

Table 2.—Average temperatures and precipitation for the months of June, July, and August, 1950, at Manhattan and Lawrence, Kansas, (Garrett 1950).

Month	Manhattan		Lawrence	
	Ave. Temp.	Ave. Precip.	Ave. Temp.	Ave. Precip.
	(° F.)	(in.)	(° F.)	(in.)
June	74.0	3.61	74.0	5.63
July	70.9	13.68	70.9	11.35
August	71.9	3.98	71.3	6.53

It was noted that the effectiveness of fly control obtained in Manhattan by the use of DDT was related in some degree to the species of flies present. This was especially true of *Phaenicia* spp. whose resting habits brought them in more frequent contact with DDT treated surfaces than did the habits of some of the other species of flies.

The cost of application of DDT for the control of flies in Manhattan during the months of June, July, and August 1950 was 9.6 cents per capita, exclusive of the salary of the supervisor, and 13.9 cents including the supervisor's salary.

Discussion.—Although the fly grill method of sampling the fly population in the city of Manhattan was used, this technique proved to be quite time consuming and hence costly for practical use in a community fly control campaign. The reconnaissance type surveys (Schoof 1951) seem to offer the advantages of rapid surveys with corresponding reductions in manpower and increase in sample size per man. Data obtained by the use of this type of survey have indicated further that the rapid visual estimates employed in the reconnaissance type of survey is for all practical purposes of accuracy equal to grill counts[9] (U. S. Public Health Service 1952, p. 39–40).

In retrospect, it would probably have been satisfactory to divide the city of Manhattan into only two sections, business and residential and most of the emphasis should have been placed upon the business districts. If rapid visual estimates had been made of the fly populations every 7 to 10 days, such as recommended in the reconnaissance type of surveys, more time would have been available for directing and evaluating the control operations.

[9] A personal communication from Dr. H. F. Schoof of the Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia indicates that additional support for this contention can be found in a manuscript in preparation by H. F. Schoof and S. Welch entitled "The Reliability of 'Visual Surveys' in Evaluating Fly Densities for Community Control Programs."

Improved sanitation and application of DDT in the city of Manhattan resulted in an average seasonal reduction of flies of approximately 70 per cent as compared with the data from the city of Lawrence in which no control program was conducted. This control was not as high, for example, as that resulting from an initial spray application of a 5 per cent solution of DDT in number 2 diesel fuel in Hattiesburg, Mississippi in 1947 (Smith 1948), where a reduction of approximately 95 per cent in the fly population was obtained. Certain unsatisfactory conditions prevailed in the Manhattan program which were beyond the control of the supervisor in charge. Prolonged, and sometimes excessive precipitation often hindered spraying operations and vitiated the effects of the spray. Also, because of other responsibilities, the spraying crew was not always available at the most opportune time for spraying. Because of inadequate funds for the purchase of the insecticide, the applications of DDT had to be limited for the most part, to those areas in the city with the highest fly populations. At times the intervals between spraying were extended over too long a period. Some of these conditions were probably not too different from those encountered in other communities however.

An important factor which developed from the experiences of this program was the desirability of having available the services of an entomologist, if only on a consulting and even part-time basis. An entomologist should work closely with the city sanitarian and city or county health officer in planning the program and should be on hand to supervise the program in its early stages. Periodic surveys of the city by an entomologist familiar with the program should be made throughout the summer and fall and his findings coordinated with the program of the city sanitarian or health officer.

Although no study was made in this program to determine whether or not DDT-resistant flies were present in the area, the recent development of flies which are resistant to the newer residual insecticides would necessitate that such a study be made with the inception of the program as a guide for planning the chemical control phase of the program.

SUMMARY.—A community fly control program was conducted at Manhattan, Kansas during the summer (June, July, and August) of 1950 following the methods of the Communicable Disease Center, U. S. Public Health Service. Periodic surveys of the city, using the Scudder fly grill, provided data on the over-all abundance of flies as well as some degree of differentiation of the abundance of certain species of flies. The data from Manhattan were compiled from an average survey of approximately 16 per cent of the total number of city blocks each week throughout the summer season. Fly population data from a nearby city (Lawrence, Kansas) of similar size and in which no fly control operations were conducted, served as a comparison for the data obtained at Manhattan. Improved sanitation and a 2.6 per cent water emulsion spray of DDT were used to reduce the fly population in Manhattan during the summer. The following conclusions can be drawn from this study:

1. A consistently lower fly population was present in Manhattan throughout the summer than in the nearby city of Lawrence which served as an untreated reference city. The seasonal over-all, weighted, city fly grill average for Manhattan was 2.1 flies per grill count and 6.6 flies per grill count for Lawrence.

2. The house fly, *Musca domestica* L., was the most abundant species of fly in both cities during the summer, making up approximately 58 and 54 per cent of the total fly population in Manhattan and Lawrence, respectively.

3. The second most abundant group of flies were the greenbottle flies of the genus *Phaenicia* (=*Lucilia*). In Manhattan these species of flies comprised approximately 28 per cent and in Lawrence, 32 per cent, of the total number of flies during the summer.

4. Blow flies of the genus *Phormia* and flesh flies of the genus *Sarcophaga* comprised less than 10 per cent of the total fly population in either city. Their trends of abundance followed those of *M. domestica* and *Phaenicia* spp. except that the highest populations occurred early in the season (June) for the blow flies and flesh flies.

5. The major fly control problem in both communities, as gauged by the highest fly population data, occurred in the business districts.

6. The fly grill method of determining fly populations would appear to be disproportionately time consuming and costly for a practical community fly control campaign. A rapid method of reconnaissance surveying would seem better for this type of program.

7. The application of the DDT water emulsion spray was largely responsible for an average of approximately 70 per cent control of flies in Manhattan during the summer as determined by comparison with the data from Lawrence, Kansas. The cost of application of DDT for the control of flies in Manhattan during the months of June, July, and August 1950 was 9.6 cents per capita, exclusive of the salary of the supervisor.

LITERATURE CITED

Baker, W. C. and L. G. Schwartz. 1947. Preliminary studies on the control of blowflies with DDT. U. S. Public Health Service. Public Health Reports. **62:** 800–7.

Bishopp, F. C. 1915. Flies which cause myiasis in man and animals—some aspects of the problem. JOUR. ECON. ENT. **8:** 317–27.

Francis, J., G. C. Brown and L. R. Penner. 1948. Search for extrahuman sources of poliomyelitis virus. Amer. Med. Assoc. Jour. **136:** 1088—93.

Herms, W. B. 1950. Medical entomology with special reference to the health and well-being of man and animals. 4th ed. New York: Macmillan. 643 p.

Hodgden, B. B. 1950. Community fly control manual. Kans. State Board of Health. 55 p.

James, M. T. 1947. The flies that cause myiasis in man. U. S. Dept. Agr. Misc. Pub. **631:** 175.

Melnick, J. L., R. Ward, D. R. Lindsay and F. E. Lyman. 1947. Fly abatement studies in urban poliomyelitis epidemics during 1945. U. S. Public Health Service. Public Health Reports. **62:** 910–21.

Melnick, J. L. 1949. Isolation of poliomyelitis virus from single species of flies collected during an urban epidemic. Amer. Jour. Hygiene. **49:** 8–16.

Paul, J. R., J. D. Trask, M. B. Bishop, J. L. Melnick and A. E. Casey. 1941. The detection of poliomyelitis virus in flies. Science. **94:** 395–6.

Sabin, A. B., and R. Ward. 1941. Flies as carriers of poliomyelitis virus in urban epidemics. Science. **94:** 590–1.

Schoof, H. F. 1951. Entomologic appraisal of fly control programs. U. S. Public Health Service. Communicable Disease Center Bul. **10**(2): 25–28.

Schoof, H. F., R. E. Siverly, and J. H. Coffey. 1951. Dieldrin as a chemical control material on community fly control programs. JOUR. ECON. ENT. **44**(5): 803–7.

Scudder, H. I. 1947. A new technique for sampling the density of housefly populations. U. S. Public Health Service. Public Health Reports. **62:** 681–6.

Smith, W. W. 1948. Reduction of fly indices in the business section of a small city by the use of DDT residual sprays. JOUR. ECON. ENT. **41:** 829–30.

Ward, R., J. L. Melnick, and D. M. Horstmann. 1945. Poliomyelitis virus in fly-contaminated food collected at an epidemic. Science **101:** 490–1.

Watt, James, and D. R. Lindsay. 1948. Diarrheal disease control. U. S. Public Health Service. Public Health Reports. **63:** 1319–34.

U. S. Public Health Service. 1950. Communicable disease center manual of operations. Entom. No. 18. May.

U. S. Public Health Service. 1952. Communicable disease center activities 1950–1951. Publication No. **204:** 39–40.

DDT and Other New Insecticides for Codling Moth Control in the Pacific Northwest

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The value of DDT for controlling the codling moth, *Carpocapsa pomonella* (L.), became established in fact not long after it was available for experimentation. Wiesmann (1943) found it to be very effective in Switzerland. Siegler (1944) made laboratory tests with it in the United States in 1943. In the same year Steiner *et al.* (1944) made tests with it in both laboratory and field. It was immediately evident that DDT was significantly more effective than lead arsenate. Many field tests were made in 1944 and 1945, and DDT was reported to be very effective for controlling the codling moth in British Columbia (Marshall 1946), Iowa (Richardson 1946) Kansas

[1] Acknowledgment of assistance in examining the fruit and in other ways is made to W. E. Westlake of this Bureau and to F. W. Carlson formerly of this Bureau.

(Parker & Eshbaugh 1947), New York (Harman 1946), Oregon (Childs 1946), and Washington (Newcomer 1946; O'Neill & Lipovsky 1946). It has since become almost universally used for this purpose by orchardists.

In order to determine the best way to use DDT in the Pacific Northwest, field tests were made from 1944 to 1950 at Yakima, Washington. Because of the danger of excessive quantities being accumulated in the soil, other insecticides were also tested.

METHODS.—Insecticides were applied to several varieties of apple trees in commercial orchards with spray guns under about 400 pounds' pressure. About 25 to 30 gallons of spray was used per tree on large trees capable of bearing 25 to 50 bushels of apples. For most of the tests three or four applications were made during the season, and a part of the work consisted in determining the optimum number of applications. As a rule eight trees, scattered at random throughout the block, were used for each test, and identical tests were made each season in two or three orchards. Jonathan, Delicious, Rome, and Winesap, the varieties most commonly grown in the Pacific Northwest, were used.

At harvest, records were taken from random samples of 250 apples from each tree. The results are shown as averages of all identical tests made during the season, even though several varieties may have been used. It was found that, although some varieties became wormier than others, even if sprayed alike, the relative value of the various treatments was similar on the different varieties.

DDT.—A preliminary test made in 1944 indicated that DDT would be of value for controlling the codling moth in the Pacific Northwest. Therefore tests were started in 1945 to determine how best to use it. One pound of 50 per cent DDT to 100 gallons of water proved to be far superior to lead arsenate at 3 pounds (Table 1). A 4-pound dosage was not much better, and 8 ounces added to 1.5 pounds of lead arsenate just about equaled the 1-pound dosage in effectiveness. An 8-ounce dosage of DDT was added to reduced dosages of lead arsenate, cryolite, xanthone, and nicotine bentonite and tried in three orchards (Table 2). In each instance much better control resulted than where the other material was used at full strength but without DDT.

In 1945 also a calyx application of lead arsenate was applied, followed by six cover sprays of DDT in two of the orchards and seven in the third orchard, which was more heavily infested, as had been the practice when lead arsenate was used throughout. In 1946, to determine whether a reduced schedule could be used (Table 3), one orchard was again sprayed a maximum of seven times and the other two six times. Omission of the calyx spray (Plot 4) did not result in any increased infestation, and omission of the second, fourth, and sixth cover sprays (Plot 5) resulted in only a slight increase. Thus, three or four applications of DDT added to xanthone were much better than six or seven applications of either lead arsenate or xanthone alone.

In 1947 and 1948 (Table 3) it was again shown that a reduced schedule adequately controlled the codling moth, and that 50 per cent DDT alone, at 2 pounds in the first cover spray and 1 pound in two or three succeeding sprays, would give as good control as a combination of DDT and xanthone. This schedule was thus adopted for experimental work, and comparison with the older insecticides was discontinued.

SUBSTITUTES FOR DDT.—It was becoming evident that periodical sprayings with DDT were resulting in an accumulation in the soil which might eventually be harmful to plant growth (Cullinan 1949). Tests were therefore started in 1948 to determine whether other insecticides might be used which would be as effective but less long-lasting in the soil. The addition to DDT of 5 ounces of 25

Table 1.—Efficiency of DDT and lead arsenate for control of the codling moth, 1945.

TREATMENT (QUANTITY PER 100 GAL.)	NUMBER PER 100 APPLES[1]	
	Worms	Injuries
Lead arsenate 3 lb., mineral oil emulsion 1 qt., colloidal spreader 2.67 oz.	13.4	37.9
DDT (50%) 8 oz., lead arsenate 1.5 lb., mineral oil emulsion 1 qt., colloidal spreader 2.67 oz.	0.9	6.0
DDT (50%) 1 lb.	0.9	4.0
DDT (50%) 4 lb.	0.5	2.4

[1] Average of 8 trees

Table 2.—Efficiency of various insecticides with and without added DDT for control of the codling moth, 1945.

Treatment (Quantity per 100 Gal.)	Number per 100 Apples[1]	
	Worms	Injuries
Lead arsenate 3 lb., mineral oil emulsion 1 qt., colloidal spreader 2.67 oz.	23.7	76.8
DDT (50%) 8 oz., lead arsenate 1.5 lb., mineral oil emulsion 1 qt., colloidal spreader 2.67 oz.	5.5	24.4
Cryolite 3 lb., mineral oil emulsion 1 qt., colloidal spreader 2.67 oz.	21.1	78.5
DDT (50%) 8 oz., cryolite 1.5 lb., mineral oil emulsion 1 qt., colloidal spreader 2.67 oz.	2.5	23.7
Xanthone 2 lb., stove oil 1 qt., colloidal spreader 8 oz.	15.8	26.6
DDT (50%) 8 oz., xanthone 1 lb., stove oil 1 qt., colloidal spreader 8 oz.	8.0	26.0
Nicotine bentonite 2 lb., mineral oil 1 qt., oleic acid 4 oz., aluminum sulfate 2 oz.	43.6	85.9
DDT (50%) 8 oz., nicotine bentonite 1 lb., mineral oil 1 qt., oleic acid 4 oz., aluminum sulfate 2 oz.	6.6	29.1

[1] Average of 24 trees.

Table 3.—Efficiency of DDT and other insecticides for control of the codling moth, 1946–50.

Plot	Treatment (Quantity per 100 Gal.)	Number of Applications	Number per 100 Apples	
			Worms	Injuries
	1946 (average of 24 trees)			
1	Lead arsenate 3 lb., mineral oil emulsion 1 qt., colloidal spreader 2.67 oz.	6 or 7	12.2	37.1
2	Xanthone 2 lb., stove oil 0.3 qt., colloidal spreader 1.3 oz.	6 or 7	15.4	24.9
3	DDT (50%) 12 oz.; xanthone 1 lb., stove oil 0.3 qt., colloidal spreader 1.3 oz.	6 or 7	2.0	6.0
4	Same as 3; no calyx spray	5 or 6	1.9	5.1
5	Same as 3; 2d, 4th, and 6th cover sprays omitted	3 or 4	2.4	7.3
	1947 (average of 21 trees)			
6	Cryolite 3 lb., mineral oil emulsion 1 qt., colloidal spreader 2.67 oz.	5 or 7	6.5	14.0
7	DDT (50%) 12 oz.; xanthone 1 lb., stove oil 0.25 to 1 pt.	5 or 7	1.1	2.4
8	DDT (50%) 1 lb.; xanthone 2 lb., stove oil 1 pt., colloidal spreader 1.3 oz.	3 or 5	1.7	3.5
9	DDT (50%) 2 lb. (1st spray), 1 lb. (others)	3 or 4	1.9	3.6
	1948 (average of 15 trees)			
10	DDT (50%) 2 lb. (1st cover), 1 lb. (others)	2 or 3	4.1	11.0
11	DDT (50%) 2 lb. (1st cover), 1 lb. (others); parathion (25%) 5 oz. (2d or 3d cover)	2 or 3	4.5	11.3
12	DDT (50%) 2 lb. (1st cover), 1 lb. (2d cover); parathion (25%) 5 oz. (2 covers)	1 or 2	5.7	15.8
13	DDT (50%) 2 lb. (1st cover), 1 lb. (others); toxaphene (50%) 1 pt. (3 or 4 covers)	2 or 4	4.0	10.6
	1949 (average of 14 trees)			
14	DDT (50%) 2 lb. (1st cover), 1 lb. (others); parathion (15%) 0.3 lb.	4	1.2	3.7
15	Parathion (15%) 1 lb.	3 or 4	8.5	12.0
16	Parathion (15%) 2 lb.	3 or 4	3.9	6.0
17	Parathion (15%) 2 lb.	2 or 3	4.5	6.8
18	Parathion (15%) 3 lb.	2 or 3	4.3	8.0
19	DDT (50%) 2 lb. (1st cover), 1 lb. (others); toxaphene (40%) 1 lb.	3 or 4	1.5	3.7
	1950 (average of 14 trees)			
20	DDT (50%) 2 lb. (1st cover), 1 lb. (others); parathion (15%) 0.5 lb.	3	1.9	3.3
21	Methoxychlor (50%) 2 lb. (1st cover), 1 lb. (others); parathion (15%) 0.5 lb.	3	1.3	1.6
22	DDT (50%) 2 lb. (1st cover); parathion (15%) 2 lb. (others)	3	3.2	4.1
23	DDT (50%) 2 lb. (1st cover); toxaphene (40%) 3 lb. (others)	3	3.2	4.4
24	DDT (50%) 2 lb. (1st cover); toxaphene (50%) 2.5 pt. (others)	3	5.9	8.4
25	Toxaphene (40%) 3 lb.	3	3.5	4.9
26	DDT (50%) 2 lb. (1st cover), 1 lb. (others) CS-708 (25%) 1 pt.	3	1.0	2.0

per cent parathion or of 1 pint of 50 per cent toxaphene (Table 3, Plots 11 and 13) gave no improvement, and the substitution of parathion for one application of DDT (Plot 12) brought about a slight increase in infestation.

In 1949 (Table 3) parathion was substituted altogether for DDT in some plots. When 1 or 2 pounds of 15 per cent parathion was used in the same number of applications (Plots 15 and 16) or 2 or 3 pounds in one less application (Plots 17 and 18), the infestation was three to seven times as great as from DDT. Again the addition of 1 pound of 40 per cent toxaphene to the DDT (Plot 19) did not improve control.

In 1950, 2 pounds of 15 per cent parathion, 3 pounds of 40 per cent wettable toxaphene, and 2.5 pints of 50 per cent emulsifiable toxaphene in two cover sprays following an initial application of DDT (Table 3, plots 22, 23 and 24) resulted in nearly twice the infestation in the plot (20) treated with DDT throughout. Driggers (1950) has shown that a high percentage of the larvae that have recently entered the fruit are killed by parathion, but it is evident from our tests that its residual effect is too short to give good control. The interval between applications was 4 to 5 weeks. Good control could probably be obtained by more frequent applications, but that would be more expensive than using DDT. The use of toxaphene alone (Plot 25) also resulted in more wormy fruit. On the other hand, there was some reduction when methoxychlor was substituted for DDT (Plot 21) or when CS-708 was added to it (Plot 26).

GROWERS' RESULTS.—In 1946 some apple growers in the Yakima Valley used DDT exclusively for controlling the codling moth, others used it only for the last one or two applications, and still others used lead arsenate or cryolite throughout the season. There was thus an opportunity of learning what success fruit growers were having with DDT. As shown in table 4, DDT gave considerably better control than did the older materials. Control of the codling moth was easier than usual in 1946, because temperatures during June and part of July had been below normal, and the differences between control with DDT and with lead arsenate or cryolite would probably have been greater in some other seasons.

There was no other opportunity to make comparisons, as the use of DDT became almost universal after 1946. In 1950 and 1951, however, records of infestation were taken in a number of orchards where various methods of application had been used in order to check on the success growers were having in controlling the codling moth (Table 5). Since in most instances the number of pounds per 100 gallons would not tell what was actually being applied to the trees, because of the various methods of application, dosages are given in terms of quantities per tree. The trees were mature and capable of bearing 25 to 50 bushels of apples each, and the orchards averaged 50 or 60 trees per acre. Parathion was added to all applications for mite control, but DDT is believed to have been the chief factor in codling moth control.

These data are not adequate to show the comparative efficiency of the methods of application, but they do show that DDT used in various ways has been extremely effective. Childs (1947) expressed the opinion that the mass reduction of moths over large orchard areas and its cumulative effect over a period of years would bring about even better results from DDT than were obtained at first. A comparison of the figures in tables 4 and 5 indicates that this has happened.

EFFECT OF DDT ON SIZE AND COLOR OF APPLES.—In the first year or two that DDT was used it was impossible to determine whether it had any effect on the size and color of the apples. Mites were so numerous in the trees and had such a marked effect on size and color that no data could be obtained. In 1945 apples from trees sprayed with DDT averaged 15 to 20 per cent smaller than those from trees sprayed with lead arsenate (Table 6). Records of color were not made that season, but it was observed that apples sprayed with DDT had much less color than those sprayed with lead arsenate. In 1947 mites were adequately controlled in some of the DDT plots, and the fruit from them was no smaller or less well colored than that not sprayed with DDT. Later comparisons could not be made, as the use of lead arsenate and cryolite was discontinued, but there has never been any evidence that DDT affects either the size or color of the fruit. In order to qualify for the extra fancy grade shown

Table 4.—Comparative efficiency of DDT, lead arsenate, and cryolite as used by apple growers for control of the codling moth, 1946.

Comparison	Treatment	Variety	Percentage	
			Wormy	Injured
1	DDT, 3 covers	Winesap	0.6	1.1
	Cryolite, 6 covers	Winesap	3.5	14.8
2	DDT, 3 covers	Jonathan	1.1	1.9
	Lead arsenate, 1 cover; cryolite, 3 covers	Jonathan	8.0	15.5
3	DDT, 2 covers (following calyx spray of lead arsenate)	Winesap	0.3	0.6
	Lead arsenate, 7 covers	Winesap	8.2	27.7
4	DDT, 2 covers (following 3 cover sprays of lead arsenate or cryolite)	Winesap	2.0	10.7
	Lead arsenate, 7 covers	Winesap	3.4	12.0
5	DDT, 1 cover (following 4 cover sprays of lead arsenate or cryolite)	Winesap	2.7	20.5
	Lead arsenate, 6 covers	Winesap	13.0	51.4
6	DDT, 1 cover (following 3 cover sprays of cryolite)	Winesap	1.3	8.7
	Lead arsenate, 1 cover; cryolite 3 covers	Winesap	3.2	20.8
	Average of DDT treatments		1.3	7.3
	Average of other treatments		6.6	23.7

in table 6, Delicious apples must have 65 per cent of the surface covered with a good shade of red, and Winesaps must have 75 per cent of the surface so covered.

RESIDUES.—Samples of harvested apples from some of the sprayed plots were analyzed for DDT residues by Westlake (Westlake & Fahey 1950). One to three applications of 50 per cent DDT at 1 or 2 pounds to 100 gallons resulted in residues of 1.0 to 3.3 p.p.m. This is well below the 7 p.p.m. that has been permitted by the U. S. Food and Drug Administration. In an earlier study of DDT residues on apples and pears in the Pacific Northwest, Walker (1948) found that one application of DDT for the second brood (about the middle of August) preceded by three or four applications for the first brood resulted in residues at harvest of less than 7 p.p.m.

ACCUMULATION OF DDT IN THE SOIL.—The soil under apple trees sprayed with DDT was examined annually for a number of years by Westlake (1950). He found that most of the DDT was in the top 3 inches of soil. In an uncultivated orchard 94 per cent of it was in the first inch, 4 per cent in the second inch, and 2 per cent in the third inch. Where there had been cultivation the percentages were 64, 23, and 13, respectively. Of course, if the cultivation extended below 3 inches there would be some DDT below that. Westlake also found that the DDT persisted in the soil and increased as additional spraying was done in the orchards. In one orchard 19 pounds of DDT per acre was found in the top 3 inches of soil after the first year's use of it. After the second year's use it had increased to 47 pounds. In another orchard there was 45 pounds

Table 5.—Effectiveness of DDT with various methods of application for control of the codling moth.

Treatment (Ounces per Tree)		Method of Application	Number of Application	Percentage	
DDT	Parathion			Wormy	Injured
1950					
3 (1st cover), 2 (others)	0.3	Air blast	3	0	0.2
6.4 (1st cover), 3.2 (2nd cover)	0.6	Duster	2	0	0
6.5	0.3	Aerosol	2	3.3	6.4
3.2	0.3	Airplane duster	2	0	0
5 (1st cover), 2.5 (others)	0.4	Spray gun	3	0.6	1.4
1951					
5	0.4	Air blast	3	0	0
3 (1st cover), 2 (others)	0.8	Air blast	3	0.8	1.7
		Air blast	1	3.2	5.9
6.4	0.6	Duster	3	1.8	4.3

after two years' use, and after the third year 79 pounds per acre. This study has not been completed, but there is indication that annual applications of DDT to the trees will result in a gradual increase in the quantity remaining in the soil. The rate of this increase will probably be slower than the rate of application, as there is still some loss.

SUMMARY.—Tests of DDT and other organic insecticides for the control of the codling moth, *Carpocapsa pomonella* (L.), in the Pacific Northwest over a period of seven seasons are reported. An initial application of 50 per cent DDT at 2 pounds to 100 gallons, followed by two or three applications at 1 pound, without the addition of any other material, gave much better control than six or seven applications of lead arsenate or cryolite. Omission of the calyx spray did not result in increased infestation. Parathion or toxaphene added to the DDT did not improve control. When used alone, even at 2 or 3 pounds, control from these materials was much poorer than from DDT, evidently owing to a shorter period of residual toxicity. Methoxychlor and CS-708 gave promise of equaling DDT. No effect on size or color of apples was observed. Residues of DDT at harvest from the schedules necessary for adequate control have always been well below the accepted limit of 7 p.p.m. There has been a gradual accumulation of DDT in the soil under apple trees sprayed with it.

Apple growers in the Pacific Northwest have had outstanding success in controlling the codling moth with DDT. A cumulative effect of using it over large areas for several years has been noticeable, control in 1950 and 1951 being considerably better than in 1946.

Table 6.—Effect of DDT on color and size of apples.

Year and Variety	Number of Trees	Average Number of Apples per Bushel		Extra Fancy Apples	
		Lead Arsenate	DDT	Lead Arsenate	DDT
1945					
Rome	8	110	135	—	—
Winesap	8	129	149	—	—
1947					
Winesap	8	126	114	66	66
Delicious	13	97	94	57	69

LITERATURE CITED

Childs, Leroy. 1946. Progress report on the use of DDT as a codling moth spray. Proc. 42d Ann. Meeting Wash. State Hort. Assoc., pp. 39–52.

Childs, Leroy. 1947. Effect of DDT on population of codling moths. JOUR. ECON. ENT. **40**(3): 452.

Cullinan, F. P. 1949. Some new insecticides—their effect on plants and soils. JOUR. ECON. ENT. **42**(2): 387–91.

Driggers, B. F. 1950. Effect of parathion on immature stages of plum curculio, oriental fruit moth and codling moth within the host plant. JOUR. ECON. ENT. **43**(4): 474–6.

Harman, S. W. 1946. DDT for codling moth control in western New York in 1945. JOUR. ECON. ENT. **39**(2): 208–10.

Marshall, J. 1946. DDT investigations in control of orchard pests in British Columbia. Proc. 42d Ann. Meeting Wash. State Hort. Assoc., pp. 66–70.

Newcomer, E. J. 1946. Growers' results with DDT for codling moth control. Proc. 42d Ann. Meeting Wash. State Hort. Assoc., pp. 55–9.

O'Neill, W. J., and L. J. Lipovsky. 1946. The results of experiments with DDT on apples at Wenatchee. Proc. 42d Ann. Meeting Wash. State Hort. Assoc., pp. 61–5.

Parker, Ralph L., and Elbert L. Eshbaugh. 1947. Codling moth and mite control in Kansas with new insecticides. JOUR. ECON. ENT. **40**(6): 861–4.

Richardson, Charles H. 1946. DDT for codling moth control. JOUR. ECON. ENT. **39**(3): 391–3.

Siegler, E. H. 1944. Laboratory tests of DDT against the codling moth. JOUR. ECON. ENT. **37**(1): 157–8.

Steiner, L. F., C. H. Arnold, and S. A. Summerland. 1944. Laboratory and field tests of DDT for control of the codling moth. JOUR. ECON. ENT. **37**(1): 156–7.

Walker, Kenneth C. 1946. Studies of DDT residue on apples and pears. Proc. 42d Ann. Meeting Wash. State Hort. Assoc., pp. 71–82.

Westlake, William E. 1950. The effect of new insecticides on the soil. Proc. 46th Ann. Meeting Wash. State Hort. Assoc., pp. 169–74.

Westlake, W. E., and Jack E. Fahey. 1950. DDT and parathion spray residues on apples. Advances in Chemistry Series **1**: 117–22.

Wiesmann, R. 1943. Weitere versuche mit gesarol in obstbau. Schweiz. Ztschr. f. Obst. u. Weinbau. **52** (6): 171–204.

A Laboratory Method for Testing Repellents against Biting Flies[1,2]

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Until recently repellents for use against livestock pests have been evaluated in the laboratory using several non-bloodsucking flies such as *Musca domestica*, L. This has been the best available procedure since bloodsucking flies have not been continuously reared in numbers large enough for extensive screening tests. For the past 5 years, however, several laboratories have been rearing *Stomoxys calcitrans* L. in numbers sufficient for such testing. Our present colony was obtained from Dr. E. J. Campau, Standard Oil of Indiana, in 1950. Even after the difficulties of rearing are finally solved, a reliable testing method with reproducible results must be found. Eddy & MacGregor (1949) have used a laboratory method in which white mice were sprayed and then exposed to starved *Stomoxys*. Although this method has many merits over semi-field testing with cattle, the numbers of white mice and their maintenance may be prohibitive in cost and space for many laboratories. It was necessary, for this and other reasons, to explore several possibilities for a rapid and comparatively inexpensive screening method.

In our present testing method rabbits are used as bait. One rabbit can be used for 40 test cages per day and can be reused within two weeks. Candidate repellents are screened as 5 per cent solutions in acetone. Two 1-foot squares of cheesecloth are placed in a dish containing 30 milliliters of the 5 per cent solution. The cheesecloth will absorb the total 30 milliliters. The treatments are hung on racks to dry at 70 to 72° F. and initial tests are conducted 24 hours later.

Plastic or glass cylinders 2 inches in diameter by 5 inches in length are used as test cages.

One end of the tube is covered with a 6 inch square of treated cheesecloth and a clean untreated square is placed over this; both are held in place by a rubber band. Five to 8-day old *Stomoxys* are released into this cylinder by placing the open end over a small opening in the top of the rearing cage. When 15 to 20 flies have entered the cylinder, the open end is covered with another untreated piece of cheesecloth. The flies can thus make direct contact with a treated cloth at one end of the cylinder cage, or if repelled, move to the end covered only with the untreated cloth. When ready for testing, the treatment end is placed against the shaven belly of a rabbit which has been immobilized dorsal side down in a holder. To feed on the rabbit, the flies must alight and bite through the treated cheesecloth. The rabbit's skin is, however, protected from contamination with the repellent by the untreated piece of cheesecloth which has been placed over the treatment. The cylinder is easily held in feeding position with a clamp on a ring stand. An acetone check treatment is used to start each day's test to determine the time necessary for ninety per cent of the flies to feed. This is normally 1 to 2 minutes. Frequent check cages are tried during the test to determine variation in feeding from one test cage to another and to detect contamination of the rabbit's skin. Each day's tests are run with a known repellent for comparison.

Testing is continued at 3 to 4-day intervals on a new portion of the repellent cloth cut from the treated material. Tests are discontinued when more than 50 per cent of the flies feed.

In establishing the screening method, several commercially available repellents were compared for use as a standard against candidate repellents. These data are presented in table 1.

Thanite and *Pyrenone 20 New* gave complete knockdown within the necessary feeding time and *Lethane 384* gave partial knockdown. They were discarded as possible standards because their knockdown properties interfered with estimation of their repellency. *Indalone* was selected as the standard material for comparison, since under these conditions it was effective for the longest time. In establishing an arbitrary letter rating system, Indalone, which usually gave over

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology.

[2] Investigations conducted under a research fellowship sponsored by Carbide and Carbon Chemicals Company at Rutgers University.

Table 1.—Comparison of commercial repellents to establish a standard in chemical screening for repellent testing against *Stomoxys calcitrans* L.

Materials	Per Cent	Per Cent Repellency in Days				
		1	4	7	10	14
Indalone	5	99.3	92.1	88.8	82.3	71.0
Crag Fly Repellent	5	51.0	49.0	53.0	57.0	41.0
Thanite[1]	5	91.0	84.0	100.0	64.0	—
Thanite[1]	3	73.0	63.0	44.0	37.0	—
6-12	5	74.0	70.0	70.0	33.0	—
Lethane 384	5	95.0	95.0	32.0	—	—
Oil of Citronella	5	62.0	20.0	—	—	—
Pyrenone 20 N[1]	2	25.0	38.0	—	—	—

[1] Knockdown within 2 minutes.
Indalone; Pyrenone 20 New—U. S. Industrial Chemical Company.
Crag Fly Repellent; 6-12 Insect Repellent—Carbide and Carbon Chemicals Company.
Thanite—Hercules Powder Company.
Lethane—Rohm and Haas Chemicals Company.

80 per cent repellency for 21 days under normal laboratory conditions, is reported as an A compound and all other materials are compared with it. A C compound is one that will give 80 per cent repellency for more than a week. An E compound is one that has given little or no protection.

During the past 5 years, repellency tests have also been conducted against laboratory reared house flies and against several species of biting flies in the field. To compare results of house fly, laboratory stable fly, and biting fly field repellency tests, an A, C, E letter rating system has been assigned to house fly and field tests with an A designating the best material for a specified time with that particular test, C showing repellency for a lesser time and E little or no repellency.

In the laboratory 111 materials were screened against *Musca domestica*, L. by the modified Kilgore bait test and against *Stomoxys calcitrans* L. by the method described. Most of the materials were originally selected on the basis of their repellency against *Aëdes aegypti* (L) or ticks, *Amblyomma americanum* (L). One hundred materials which were at least 80 per cent repellent for more than 10 days (A–C) to house flies were tested against *Stomoxys*, and 11 materials which were repellent against ticks were tested against both house flies and stable flies. Results are given in table 2.

Of the 111 compounds, 49 per cent rated A against *Musca*, only 4 per cent rated A against *Stomoxys*. Of 41 per cent showing C repellency against house fly, only 10 per cent gave C repellency against the stable fly, while 86 per cent of these

Table 2.—Rating comparison of 111 repellents tried against *Musca domestica* and *Stomoxys calcitrans*, expressed in per cent.

		House Flies			Total Per Cent *Stomoxys*
		A	C	E	
STOMOXYS	A	3	1	0	4
	C	5	5	0	10
	E	41	35	10	86
	Total % Musca	49	41	10	

compounds gave no repellency against *Stomoxys* as compared to 10 per cent with *Musca*. Ten per cent of the materials rating E on both *Stomoxys* and house flies were the 11 materials showing repellency to ticks. Of approximately 800 materials tested against house flies, 13 per cent rated A, while only 4 per cent of 500 materials tested against stable flies gave gave an A rating.

These figures indicate that screening against *Stomoxys* was more selective than screening against house flies in laboratory tests, and that there was little correlation between repellency ratings.

Thirteen of these same materials tried in the laboratory were applied in an oil base in New Jersey field tests. The results are shown in Table 3.

Table 3.—Comparison of field repellency tests with laboratory repellency tests against *Musca* and *Stomoxys*.

Material 5%	House Fly	*Stomoxys*	Field[1]
Indalone	C	A	E
Thanite	C	C	E
Deobase	—	E	C-E
R-236	A	A	C
R-285	A	E	C
968	A	A	C
Crag Fly Repellent	C	C-E	A-C
1213	A	E	E
1330	C	C	C
1481	C	E	C
1849	C	E	C
1871	C	E	C
5770	A	C	C
6073	—	A	C
6077	—	A	C
6226	—	A	E
6266	—	C	A

[1] Mixed population combination of *Stomoxys calcitrans* L. and *Siphona irritans* L.

In working with any one material, great variation in repellency has been observed from week to week and from season to season where the same cattle

have been sprayed, and fly counts on unsprayed animals have been comparable. *Crag Fly Repellent*, variable in the field from A through C, has given only partial repellency or none at all in the laboratory, while Indalone, unusually effective in laboratory testing, has given little protection in the field. Five other materials which have shown effectiveness against *Stomoxys* in the laboratory equivalent to Indalone, have given protection in the field, with one exception, Compound Number 6226.

Several ideas were projected to find reasons for these discrepancies. Consideration was given to the manner of storage of repellent cloths, materials used as diluents, and variation in conditions on the animal's skin.

In several tests during the 1950 summer season *Indalone* cloths were dried in the open and in the laboratory. The duration of repellency in these tests was not appreciably reduced. Recently laboratory treatments have been stored in a cabinet fitted with an exhaust fan which continuously pulls a stream of air over the cloths. This has cut down the length of repellency, but has not changed the order of effectiveness.

While acetone is normally used in the laboratory as the solvent, water emulsions and a refined kerosene type oil (the field diluents) were also tried in laboratory tests with *Indalone*, *Crag Fly Repellent* and *Compounds 968* and *6073*. The oil and acetone solutions of *968*, *Indalone* and *6073* gave protection for more than 2 weeks in the laboratory, while the water emulsions gave protection up to a week longer. Crag with the three carriers gave about 50 per cent repellency at 24 hours.

It has been known for some time that breakdown of repellents applied to human skin can be hastened by the production of sweat. Recent work by Findlay & Yang (1950) in breeding cattle for tropical climate has shown that Ayrshire cattle do have numerous sweat glands of modified apocrine type, and each hair follicle is associated with a sweat gland as well as a sebaceous gland. Chemical studies of these sweat glands are being conducted (Yang 1952), but since complete data was not available, a formulation for human sweat was obtained through W. R. Kirner, National Research Council, December 7, 1951. Preliminary tests have been conducted with this formulation in combination with repellents by placing a 6-inch square of cheesecloth saturated with sweat solution over the treatment end of the plastic cage. Results of these tests conducted at intervals over a 6-month period are given in table 4.

Table 4.—Influence of synthetic sweat on three chemicals tested as repellents 24 hours after treatment. Recorded as per cent feeding in 5 minutes.

CONDITION	CHECK	Indalone	Crag	6226
Dry	90	0	59	7
Distilled water	84	2	32	5
Synthetic sweat	88	45[1]	0	39[1]

[1] Mildly toxic at 5 minutes. Flies recovered at 30 minutes and completed feeding with no apparent repellency.

Indalone, *6226*, and *Crag Fly Repellent* retain the same order of repellency with moisture as they do in the dry state. Synthetic sweat, on the other hand, appears to influence favorably the degree of repellency of Crag and to have the opposite effect on *Indalone* and *Compound 6226*. Discrepancies between laboratory and field results may be partly accounted for by these observations.

SUMMARY.—A 5-per cent solution of the candidate repellent is used to saturate two one-foot square pieces of cheesecloth. Six-inch pieces are cut from the treated cloth and used to cover one end of a 2 by 5 inch glass or plastic cylinder cage. After the cage is loaded with stable flies, *Stomoxys calcitrans* L., the other end is covered with an untreated piece of cheesecloth. To test, the cage is held treated side down on the shaven belly of a rabbit, and the number of flies feeding is observed. Tests are normally made from freshly cut pieces 24 hours after treatment and at weekly intervals until 50 per cent or more of the flies feed. In comparisons of laboratory repellency tests between house flies and *Stomoxys*, little correlation has been noted. Discrepancies between laboratory tests with *Stomoxys* and field tests with biting flies are partly accounted for by data obtained by laboratory testing with a synthetic sweat formula.

LITERATURE CITED

Eddy, Gaines W. and W. S. McGregor. 1949. Use of white mice for testing materials used as repellents and toxicants for stable flies. JOUR. ECON. ENT. 42(3): 461–3.

Findlay, J. D. and S. H. Yang. 1950. The sweat glands of Ayrshire cattle. The Journal of Agricultural Science 40(1–2): 126–33.

Kilgore, L. B. 1939. Insect repellents. A study of the comparative repellency by the sandwich-bait method using confined house flies. Soap 15(6): 103, 105, 107, 109, 111, 123.

Yang, S. H. 1952. Histochemical studies on bovine sweat glands. The Journal of Agricultural Science 42(1–2): 155–8.

Efficiency of Sulfhydril Compounds in the Detoxication of Arsenite in Two Species of Insects[1,2]

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The investigation of the role of the sulfur-bearing amino acids in the detoxication processes in insects was undertaken as part of an overall investigation of the functions of amino acids in these forms. Methionine, cysteine, cystine and the tripeptide glutathione were studied, and the effect of these upon the toxicity of arsenite was compared with the protective activity of 2,3-dimercaptopropanol (BAL).

The activity of sulfhydryl groups as arsenic receptors in animals has been the subject of investigation for a number of years. Voegtlin *et al.* (1925) injected rats with a minimum lethal dose (MLD) of an arsenoxide (3-amino, 4-hydroxyphenylarsenious oxide) and found that injected or ingested glutathione or cysteine would reduce the toxicity of this arsenical. Trypanosomes survived toxic doses of arsenoxide and arsenious acid in the presence of reduced glutathione (GSH), as was pointed out by Rosenthal & Voegtlin (1930). It was suggested by Voegtlin that the toxicity of the arsenical was due to the chemical combination of arsenic with tissue GSH or other protoplasmic thiols, and that the protective action of added monothiols was due to competitive reaction with arsenic in the same way. Barron & Singer (1943) observed that many animal oxidases are inhibited by reagents which combine with the SH groups necessary for activity, and that these enzymes are reactivated by GSH. One such reagent was an organic trivalent arsenical. The most conclusive evidence is that of Peters *et al.* (1945) who, in their efforts to find an antidote for the trivalent arsenical gas lewisite, identified the pyruvate oxidase system as the site of intense inhibition by arsenite. Pyruvate oxidase is neither reactivated nor protected by monothiols such as GSH and cysteine. They observed from early reports that GSH does not give complete protection to the organism and that the degree of protection is not the same with all arsenicals. They demonstrated that the reaction between arsenite and simple monothiols yields compounds which are easily hydrolyzed. The compounds of protein sulfhydryl groups and arsenite are slightly more stable, while the thioarsenites of simple dithiols are many times more stable than the first two types. They found that simple dimercapto compounds would give complete protection against arsenite and lewisite intoxication in rats and humans. The compound 2,3-dimercaptopropanol which was later called British anti-lewisite or BAL proved to be the best for therapeutic use. Its activity has been thoroughly investigated in connection with arsenic poisoning in mammals. To explain the greater protection afforded by dithiols it was postulated that thioarsenites having a ring structure are preferentially formed, and are more stable than those in which two monothiol radicals linked through the arsenious ion are not joined to each other. The evidence for the concepts formulated by Peters and his co-workers is reviewed by Waters & Stock (1945) and is considered to be conclusive.

[1] The data presented herein were derived in part from the Master's thesis of A. D. Anderson accepted in partial fulfillment of requirements by Cornell University, 1951.

[2] This investigation was supported in part by a grant from the Lalor Foundation of Wilmington, Delaware.

In the case of insects, the investigations have not been so thorough. Fink (1927) found a decrease of 28 to 46% in the GSH content of insects from 10 species after treatment with arsenic pentoxide and trioxide. Forgash (1951) observed a decrease of GSH in *Periplaneta americana* with arsenic trioxide, dibasic sodium arsenate and cupric chloride. Glutathione injected before or after arsenic trioxide reduced the toxicity of the arsenic. It was more effective if given before the arsenical. These data indicate that the mechanism of action of arsenic is at least similar in insects to that demonstrated for vertebrates in that the receptor is a sulfhydryl compound.

METHODS.—The experimental insects, *Musca domestica* adults and *Tenebrio molitor* larvae, were cultured according to standard procedures. The house flies were reared on the medium formulated by Richardson (1932) and the adults were fed dilute skim milk. The *Tenebrio* larvae were reared on dry dog food. They were taken from cultures within 4 months of the same age and were selected for uniform development by selecting larvae of a predetermined length (2.7 to 3.0 cm.).

The houseflies were injected with arsenite solutions formulated to hold the volume injected constant at 1.1 microliters. Injections were done in replicates of 10 insects for each determination. The flies were anesthetized with CO_2 gas and the tip of the injection needle (a 30-gauge hypodermic needle) was introduced into the abdomen just under and parallel to the integument. The amino acids methionine, cysteine, and cystine were used. Methionine and cystine were fed to both larvae and adults. Cysteine was given by injection into adults only. Treated flies were held at 27° C. The per cent mortality was recorded after 24 hours. Since houseflies starve quickly all were fed dilute skim milk during the holding period. Check replicates were injected with distilled water and held in the same way.

The mealworms were treated with cysteine, glutathione and BAL. The replicates averaged 22 insects for all treatments. When solutions of glutathione were prepared, the reagent was first treated with zinc dust and dilute HCl to reduce any oxidized material. The larvae were injected between the second and third abdominal segments with an injection apparatus similar to that used with house flies. All of the materials were introduced as aqueous solutions not more than 30 minutes after injection of arsenite. The volume varied from 1 to 7 microliters. The amount of each thiol used was:

LD-50 arsenite	4.9 micrograms	0.04 micromoles
Cysteine	45 micrograms	0.3 micromoles
Glutathione	135 micrograms	0.4 micromoles
BAL	4.5 micrograms	0.04 micromoles

The larvae were held without food or water for 24 hours at 26° C. and the per cent mortality was recorded. The larvae were considered dead if they failed to respond to contact with a hotplate at low heat.

Table 1.—Effect of feeding methionine on the toxicity of sodium metarsenite to the housefly.

SEX	CONCENTRATION OF METHIONINE FED	ARSENITE MICROGRAMS/GRAM	AVERAGE PER CENT MORTALITY
Male	None	17	47.7
Female	None	31	50.9
Male	0.05 M	17	40.0
Female	0.05 M	31	40.0
Male	0.1 M	17	49.5
Female	0.1 M	31	93.3

RESULTS.—In evaluating the results, slight differences were tested for significance by statistical methods. Obvious differences were not so tested. In the case of the housefly, the data were corrected for mortality in the check replicates by the formula of Abbott (1925). No significant decrease in toxicity of sodium ar-

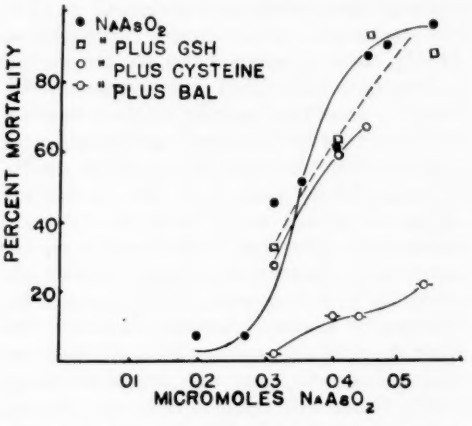

FIG. 1.—Mortality curves for larvae of *Tenebrio molitor* injected with sodium metaarsenite, arsenite plus glutathione, arsenite plus cysteine, and arsenite plus BAL (2,3-dimercaptopropanol).

senite to the housefly was observed with methionine, cystine or cysteine. Methionine was found to be toxic per se in high concentrations; it was observed to increase the susceptibility of adult females to arsenite. (Table 1.)

With *Tenebrio molitor*, cysteine and glutathione gave a slight reduction in per cent mortality at the lowest level tested, but the difference was not statistically significant according to the method of Litchfield & Wilcoxon (1949). BAL in a 1:1 molar ratio to the LD-50 gave excellent protection and reactivation. That the efficiency of protection is almost 100 per cent is illustrated by figure 1. At and below the LD-50 the concentration of BAL is as great as or greater than the concentration of the arsenical, and the protection or reactivation is complete. Above that dosage level not all of the toxicant is inactivated, and a dosage-mortality curve displaced to the right is obtained.

DISCUSSION. Glutathione and cysteine failed to detoxify sodium metarsenite in the proportions used. This is contrary to the results reported with arsenic trioxide, arsenic pentoxide and organic arsenicals. However, Schmitt & Skow (1930) stated that GSH would delay but not prevent the extinction of the action potential of peripheral frog nerve by arsenite. Peters reported that the brain pyruvate oxidase system is not protected against lewisite or sodium arsenite by GSH even in a molar ratio of 1:220. Strangeways (1937) reported the inhibition of the lethal action to trypanosomes of an arsenoxide and a thioarsenite in concentrated solutions by a 10 molar excess of GSH, but the failure of a similar excess to protect against the toxicity of very dilute solutions. This phenomenon is due to the rapid hydrolysis of the thioarsenite formed, with the liberated arsenoxide causing the toxicity.

The data presented in the experiments on insects reported here agree with the results obtained with sodium arsenite in vertebrate studies. They are not in agreement with the hypothesis that glutathione is the primary arsenic receptor in insects, although the reaction undoubtedly occurs. If the toxicity were due to depletion of glutathione, the excess of that substance injected in these tests should be more than adequate to replace that inhibited by combination with trivalent arsenic, and no metabolic disturbance should occur. The disparate results observed with sodium arsenite as compared to arsenic trioxide and organic arsenicals need to be explained. An obvious reason from previously recorded evidence, particularly that of Stocken & Thompson (1946), is that the glutathione-arsenic trioxide compound is more stable than that formed with sodium metarsenite. The relative solubilities of the two arsenicals in water may also influence the detoxication. The trioxide is only soluble to the extent of 2 to 3 grams per 100 ml., while sodium arsenite is very soluble. It would be logical to assume from this that the arsenite will be distributed more rapidly and will penetrate more readily than the oxide, so that detoxication would have to occur more rapidly to prevent intoxication.

SUMMARY.—Methionine, cystine, cysteine, reduced glutathione and BAL (2,3-dimercaptopropanol) were fed or injected into adult house flies and mealworm larvae, and the effect of this treatment upon the toxicity of sodium metarsenite was determined.

Methionine, cystine, cysteine and glutathione failed to give any significant detoxication. BAL was highly effective in detoxifying arsenite in the mealworm in a 1:1 molar ratio at the LD-50.

In accordance with these data and the evidence from vertebrate studies, it may be concluded that the primary arsenic receptor in the mealworm is a sulfhydryl-containing compound or system component, other than glutathione, and possibly an oxidative enzyme.

LITERATURE CITED

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. JOUR. ECON. ENT. **18:** 265–7.

Barron, E. S. G. and T. P. Singer. 1943. Enzyme systems containing active sulfhydryl groups. The role of glutathione. Science **97:** 356–8.

Fink, D. E. 1927. Is glutathione the arsenic receptor in insects? JOUR. ECON. ENT. **20:** 794–801.

Forgash, A. J. 1951. The effect of insecticides and other toxic substances upon the reduced glutathione of *Periplaneta americana*. JOUR. ECON. ENT. **44:** 870–8.

Litchfield, J. T., Jr. and F. Wilcoxon. 1949. A simplified method of evaluating dose-effect experiments. Jour. Pharm. & Expt. Therap. **95:** 99–113.

Peters, R. A., L. A. Stocken, and R. H. S. Thompson. 1945. British anti-lewisite. Nature **156:** 616–9.

Richardson, H. H. 1932. An efficient medium for rearing houseflies throughout the year. Science **76**: 350–1.
Rosenthal, S. M. and C. Voegtlin. 1930. Biological and chemical studies of the relationship between arsenic and glutathione. Jour. Pharm. and Expt. Therapy. **39**: 347–67.
Schmitt, F. L. and R. K. Skow. 1934. The mechanism of the arsenite action on medullated nerve. Am. Jour. Physiol. **111**: 711–9.
Stocken, L. A. and R. H. S. Thompson. 1946. British Anti-lewisite. 2. Dithiol compounds as antidotes for arsenic. Biochem. Jour. **40**: 535–48.
Strangeways, W. I. 1937. The trypanocidal activity in vitro of aromatic thioarsinites and neoarsphenamine. Ann. Trop. Med. **31**: 387.
Voegtlin, C., H. A. Dyer, and C. S. Leonard. 1925. On the specificity of the so-called arsenic receptor in the higher animals. Jour. of Pharm. and Expt. Therap. **25**: 297–307.
Waters, L. L. and C. Stock. 1945. BAL (British Anti-Lewisite). Science **102**: 601–6.

Insecticidal Control of Rhodes Grass Scale on St. Augustine Grass Lawns

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Rhodes grass scale, *Antonina graminis* (Mask.), seemingly produces severe injury to St. Augustine grass lawns in the Winter Garden area during the summer. This grass ordinarily produces an attractive green cover with only moderate care. In 1948, in spite of careful fertilization and watering, lawns infested with Rhodes grass scale sometimes lost their color and natural vigor.

The adult scale insects have small dark bodies covered with a white growth and resemble cotton balls of various sizes. The attached non-motile adults and attached young are found during the spring, summer and fall around the nodes beneath the base of the grass blades. During the winter, the mature adults are found on the roots. The crawlers, or newly born young, are very active, small, dark insects which are found on any part of the plant. Crawlers were observed as late as December in 1949, and as early as March 20 in the spring of 1950. The scale has been found on lawns in the Winter Garden area each summer since 1948 and has probably been here for several years prior to this date.

This scale was found on Rhodes grass near Kingsville in 1942 (Potts & Hensel, 1947). It has been a limiting factor in the production of Rhodes grass in south Texas since about 1940, reducing plantings to a short life of about 3 years, whereas, formerly, these plantings would last from 6 to 10 years (Riherd & Chada, 1952).

Rhodes grass scale has been found on 74 species of grasses. Some resistance to attack has been found in some of them; a few others are very susceptible to attack. The scale has been found in 63 counties in Texas (Riherd & Chada, 1952).

The prevalence of the scale on St. Augustine grass lawns in Crystal City and Carrizo Springs in 1948 and the poor condition of these lawns at the same time time seemed significant. This led to the conducting of insecticidal experiments on St. Augustine grass lawns in Crystal City during the summer of 1948. A repetition of the most favorable experiment in 1948, a trial of new insecticides, and an experiment to determine the interval necessary between applications were conducted in 1949. New materials were compared with parathion in 1950.

PROCEDURE.—The sprays were applied with a 3-gallon garden sprayer; dusts were applied through a loose mesh bag. Normal watering of the lawns was continued after the insecticides were applied.

In 1948 the plots were limited to 16 square feet in area with 4 replications. The plots in later experiments were increased to 64 square feet in area.

The treatments were evaluated in 1948 by collecting five 6-inch St. Augustine grass runners from each plot and counting the living scales on these runners through a field lens. This necessarily slow method sometimes extended the taking of records to a period of 3 or 4 days. Data from later experiments were taken from sample runners containing five nodes, regardless of length, because the number of nodes in a 6-inch runner varies and most of the scales are found surrounding the node beneath the base of the leaf.

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Table 1.—Comparison of insecticides for the control of Rhodes grass scale. Crystal City, 1948.

Treatment	Gallons or Pounds of Spray or Dust per Acre	Pounds of Active Ingredients per Acre	3 Days After Application	
			Average Scales per Plot	Per Cent Reduction
gBHC Spray, 2 lbs. of 50% wettable powder per 100 gallons	1000	10.0	73.2	0.0
Chlordane Spray, 2 lbs. of 50% wettable powder per 100 gallons	1000	10.0	67.0	4.3
DDT Spray, 2 lbs. of 50% wettable powder per 100 gallons	1000	10.0	62.5	10.7
Rhothane Spray, 2 lbs. of 50% wettable powder per 100 gallons	1000	10.0	67.0	4.3
Parathion Spray, 2 lbs. of 25% wettable powder per 100 gallons	1000	5.0	0.5	99.3
1% Parathion Dust	200	2.0	2.8	96.0
1.5% Summer Oil Emulsion	1000	15.0	42.4	39.4
Check			70.0	
Minimum Significant Difference, At 5 per cent, 21.2, At 1 per cent 28.8				

Table 2.—Comparison of various concentrations of parathion dusts and sprays for the control of Rhodes grass scale on St. Augustine grass. Crystal City, 1948.

Treatment	Gallons or Pounds of Spray or Dust per Acre	Pounds of Active Ingredients per Acre	7 to 8 Days After Application	
			Average Scales per Plot	Per Cent Reduction
25% wettable powder				
2 lbs. per 100 gallons	500	2.5	0.8	97.5
1 lb. per 100 gallons	500	1.25	1.3	96.0
0.5 lb. per 100 gallons	500	0.625	2.5	92.3
0.25 lb. per 100 gallons	500	0.313	1.0	96.9
Parathion dust				
1%	200	2.0	2.8	91.4
1%	100	1.0	3.3	89.8
1%	50	0.5	4.3	86.8
1%	25	0.25	3.5	89.2
Check			32.5	
Minimum Significant Difference, At 5 per cent, 3.6, At 1 per cent 4.9				

Table 3.—Comparisons of various concentrations of parathion dusts and sprays for the control of Rhodes grass scale on St. Augustine grass. Crystal City, 1948 and 1949.

Treatment	Gallons or Pounds of Spray or Dust per Acre	Pounds of Active Ingredient per Acre	November 1948				June 1949			
			3 to 6 Days After Application		15 to 17 Days After Application		3 to 5 Days After Application		8 to 10 Days After Application	
			Average No. of Scales per Plot	Per Cent Reduction	Average No. of Scales per Plot	Per Cent Reduction	Average No. of Scales per Plot	Per Cent Reduction	Average No. of Scales per Plot	Per Cent Reduction
25% wettable powder:										
0.5 lb.	200	0.25	9.5	72.9	0.7	97.3	11.0	87.6	43.0	56.5
0.25 lb.	200	0.125	21.8	37.7	2.3	91.1	10.8	87.8	81.8	17.2
Dust:										
1%	50	0.5	16.0	55.3	3.8	85.2	21.5	75.7	75.5	23.6
1%	25	0.25	19.3	73.4	9.3	63.8	25.3	71.4	73.3	25.8
0.25%	50	0.125	10.0	71.4	8.0	68.9	28.8	67.5	60.0	39.3
Check			35.0		25.7		88.5		98.8	
Minimum Significant Difference										
At 5% level			14.6		7.2		18.7		35.3	
At 1% level			20.2		10.3		25.9		48.8	

Table 4.—Insecticide control of Rhodes grass scale on St. Augustine grass lawns. Crystal City, 1949.

Treatment	Gallons of Material per Acre	Pounds of Active Ingredients per Acre	5 Days After Application	
			Average No. of Scales per Plot	Per Cent Reduction
25% Parathion wettable powder—0.5 lb. per 100 gallons	200	0.25	37.0	79.4
20% TEPP—1 Quart per 100 gallons	200	0.80	88.8	50.5
Check			179.5	
Minimum Significant Difference				
At 5% level			39.2	
At 1% level			59.4	

1948 EXPERIMENTS.—In the first experiment conducted in 1948, several organic insecticides and a summer oil emulsion were tested. Parathion, in both spray and dust form, was the only material which gave favorable results. The summer oil emulsion gave slight control but damaged the grass.

The second experiment of this season was with various concentrations of parathion sprays at a reduced rate per acre and with 1 per cent parathion dust at various rates per acre. All treatments were very favorable, indicating that a low rate per acre was sufficient.

Therefore, the third experiment of 1948 was with a reduced rate of sprays of low concentrations and with 0.25 per cent and 1 per cent dusts at a low rate per acre. A spray of 0.5 pound per 100 gallons at 200 gallons per acre and at 1 per cent dust at the rate of 50 pounds per acre gave best results. Tables 1, 2 and 3 show the results of these experiments.

1949 EXPERIMENTS.—In order to substantiate the preceding results, a repetition of the test was set up in June of 1949. Results were somewhat simliar but the longer residual effect in the 1948 experiment shows the probable difference between June and November temperatures on the dissipation of parathion. The results of the two experiments can be compared in Table 3.

The possibility of finding another insecticide for control led to the experiment in table 4. TEPP was ineffective in controlling Rhodes grass scale.

The need to determine the interval between applications of parathion for practical control resulted in the experiment shown in table 5. The parathion sprays and dusts at favorable rates were applied at weekly intervals, four applica-

Table 5.—Control of Rhodes grass scale on St. Augustine grass lawns at various dosages of parathion applied at weekly intervals[1] with weekly records. Crystal City, 1949.

Treatment	Gallons of Material per Acre	Pounds of Ingredient per Acre	3 to 5 Days After 2nd Application		3 to 5 Days After 3rd Application		3 to 5 Days After 4th Application		10 to 11 Days After Application		17 to 18 Days After Application	
			Ave. No. of Scales per Plot	Per Cent Reduction	Ave. No. of Scales per Plot	Per Cent Reduction	Ave. No. of Scales per Plot	Per Cent Reduction	Ave. No. of Scales per Plot	Per Cent Reduction	Ave. No. of Scales per Plot	Per Cent Reduction
Parathion 25% wettable												
0.5 lb. per 100 gal.	200	0.250	12.3	90.6	4.0	96.6	13.0	89.2	56.8	60.0	107.0	29.0
0.25 lb. per 100 gal.	200	0.125	30.0	77.2	28.8	75.8	30.3	74.9	104.8	26.2	112.3	25.5
Parathion Dusts												
1%	50	0.500	7.5	94.3	3.8	96.8	9.3	92.3	33.5	76.4	61.0	59.5
1%	25	0.250	48.0	63.4	30.3	74.5	28.8	76.1	54.8	61.4	90.0	40.3
0.25%	50	0.125	31.0	76.4	24.8	79.1	20.0	83.4	65.5	53.9	67.3	55.4
Check			131.3		120.5		118.8		142.0		150.8	
Minimum Significance Difference												
At 5% level			15.4		22.8		22.8		40.5		53.8	
At 1% level			21.3		31.6		31.6		55.9		74.4	

[1] Four applications were made at weekly intervals on August 29, September 5, 12, and 19. Records were taken over the period from August 29 to October 7.

Table 6.—Comparison of aldrin and dieldrin in various forms with parathion in the control of Rhodes grass scale on St. Augustine grass lawns. Winter Haven, 1950.

Treatment	Gallons of Material per Acre	Pounds of Active Ingredient per Acre	6 to 9 Days After Application		11 to 14 Days After Application	
			Average No. of Scales per Plot	Per Cent Reduction	Average No. of Scales per Plot	Per Cent Reduction
Aldrin: Emulsion						
0.5 lb. per 100 gal.	200	0.50	157.5	0	190.0	0
25% wettable powder						
0.5 lb. per 100 gal.	200	0.50	166.0	0	154.8	0
1% dust	50	0.50	179.3	0	168.5	0
Dieldrin: Emulsion						
0.5 lb. per 100 gal.	200	0.50	215.8	0	184.8	0
25% wettable powder						
0.5 lb. per 100 gal.	200	0.50	165.3	0	141.5	7.5
1% dust	50	0.50	183.8	0	208.0	0
Parathion						
25% wettable powder						
0.5 lb. per 100 gal.	200	0.50	47.8	54.4	179.5	0
1% dust	50	0.50	27.8	73.5	165.0	0
Check			104.8		153.0	
Minimum Significant Difference						
At 5% level			52.5			
At 1% level			71.2			

tions being made. Records were taken at weekly intervals. Parathion spray at the rate of 0.5 pound of 25 per cent wettable powder at 200 gallons per acre and 1 per cent parathion dust at 50 pounds per acre were most effective. The decreased residual effect 10 and 17 days after treatment prove the necessity of more frequent applications. The continuous large reduction of the scale population when applications were repeated weekly shows the possibility of control during the summer if several applications are made. The two dusts at the rate of 50 pounds per acre had longer residual effect than the two spray concentrations used.

1950 EXPERIMENT.—With the availability of aldrin and dieldrin formulations in 1950, experiments with them in comparison with a parathion spray and dust, as shown in table 6, were conducted. Aldrin and dieldrin dusts and wettable powder and emulsion sprays were of no value in reducing the population of Rhodes grass scale. The 1 per cent parathion dust was more effective than the spray in this test.

In another experiment, EPN and a calcium sulphate material, called Agrisul, were ineffective in controlling the scale. Agrisul plots even showed an increase in scale insect population.

Table 7.—Comparison of insecticides for the control of Rhodes grass scale. Crystal City, 1950.

Treatment	Gallons per Acre	Pounds of Active Ingredient per Acre	4 to 5 Days After Application	
			Average No. of Scales per Plot	Per Cent Reduction
Calcium sulphate—6 gal. per 100 gal.	200	12.00	122.8	0.00
EPN—25% wettable powder—0.5 lb. per 100 gallons	200	0.25	78.3	30.1
25% Parathion wettable powder—0.5 lb. per 100 gallons	200	0.25	24.5	78.1
Check			112.0	
Minimum Significant Difference				
At 5% level			27.9	
At 1% level			40.0	

SUMMARY.—A parathion spray with 0.125 pound of actual material in 200 gallons of water per acre was almost as effective in the control of Rhodes grass scale on St. Augustine grass lawns as concentrations ranging from 0.313 to 2.5 pounds of actual material in 500 gallons of water per acre. Five pounds of actual parathion in 1000 gallons of water per acre did not give significantly better control than the 200 gallon application. There was no significant difference between 1 per cent parathion dust treatments at the rate of 25, 50, 100 and 200 pounds per acre. These sprays and dusts were most effective when repeated at weekly intervals. Longer residual effect was obtained during cool weather.

Chlordane, gBHC, DDT and rhothane wettable powders at the rate of one pound of actual material in 1000 gallons of water were ineffective in the control of the scale. One and a half per cent summer oil emulsion was more effective than the preceding materials but injured the grass. Two quarts of TEPP in 200 gallons of water per acre was ineffective. Aldrin and dieldrin 1 per cent dusts and emulsion and wettable powder sprays, an EPN spray, and a calcium sulphate spray were ineffective in reducing the scale population.

It was found that 1 per cent parathion dust at 50 pounds per acre or parathion spray containing 0.25 pound of actual material in 200 gallons of water per acre applied at intervals of 1 week to 10 days should give control of crawler and young established Rhodes grass scale insects on St. Augustine grass lawns in the Winter Garden area.

LITERATURE CITED

Potts, R. C. and R. L. Hensel. 1947. Rhodes grass in Texas. Texas Agr. Expt. Sta. Circ. **116.**
Riherd, Paul T. and H. L. Chada. 1952. Some scale insects attacking grasses in Texas. Texas Agr. Expt. Sta. Prog. Rpt. **1461.**

Control of Immature Stages of the Boll Weevil[1]

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Chemical control for the immature stages of the boll weevil *Anthonomus grandis* Boh. received very little attention until the chlorinated hydrocarbons became available. The potential economic value of these new insecticides was realized when it was demonstrated that some were effective in controlling the boll weevil developing within squares.

Rainwater (1947) using field treated squares found chlordane and benzene hexachloride dusts toxic to boll weevils developing within squares.

Gaines & Scales (1948) found squares treated in the field with parathion or toxaphene dusts had little effect upon the developing boll weevil. Chlordane dust caused a high mortality of weevils within the squares while benzene hexachloride was somewhat less effective.

METHODS.—During the season of 1952 several tests were conducted at the College Station Laboratory and in nearby fields in an effort to evaluate a number of commonly used organic insecticides for the control of the developing stages of the boll weevil within the squares. Abbott's formula was used to calculate all the percentage mortalities.

Laboratory tests.—A sample of 100 squares was arranged on a clean paper in such a manner that none was touching the other. A large aluminum cylinder, 54 inches high and 34 inches in diameter, was placed over the sample of squares. Each insecticide was sprayed into the top of the cylinder by compressed air at a pressure of 40 pounds per square inch.

After spraying, the squares were allowed to remain under the cylinder for 3 minutes and then transferred to clean rearing cages. The rearing cages consisted of wood frames which were covered with a close-mesh screen wire. One series of samples treated in this manner were placed in clean rearing cages made of wood frames which were covered with close mesh screen wire. These 12 by 12 by 12 cages had a removable lid facili-

[1] Technical Contribution No. 1722, Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

tating easy transfer of material to and from the cage. From each cage four large vials protruded into the light in such a manner that the emerging weevils were attracted into these vials. This series consisted of 10 insecticidal treatments and a check replicated 5 times.

Another series of samples were treated in the same manner using the same insecticides and dosages. These samples were placed on the ground in the field and covered with 2 by 2 by 2 screened field cages. Each treatment was replicated four times. The cages in both series were examined twice daily and the adult weevils were removed and the number recorded. Upon completion of emergence the squares were opened and examined for live and dead larvae, pupae and adults. In this manner the stage in which mortality occurred was determined.

Tests similar to the above described series were conducted using bolls infested with weeveils. Only the chlorinated hydrocarbons were employed in these tests. One hundred punctured bolls received the same treatment as the squares in the previous tests. The treated bolls were placed in rearing cages in the insectary and daily records were made of the number of dead and live weevils. Before the test was completed the bolls dried out and burst open, thereby liberating many adults that may have died as a result of either insecticidal action or natural causes. In these tests the latter were counted as live weevils even though they were unable to come to the vials.

Hanging square tests.—The number of squares punctured by weevils on selected plants were recorded before the treatments were made. The plants were thoroughly examined and all adult weevils were removed in order to prevent reinfestation. The aluminum cylinder used in the laboratory series was placed over the plant and the spray was applied as described above. The same dosages as used in the laboratory were used in this series. After treatment the cylinder was removed and each plant was caged with a 2 by 2 by 2 screen wire field cage. Daily examinations of each plant were made for a period of 20 days. Five replicate plants were treated with each insecticide listed in table 2 and each series included an untreated plant to serve as a check.

Field tests.—The third series of tests was conducted by collecting squares from a field, treated for weevil control with a power sprayer in the usual manner. The squares were taken from four field tests, the plats in each test were arranged in randomized blocks. Each treatment and check was replicated four times. The insecticides and dosages used are listed in

Table 1.—The percentage mortality of weevils within squares treated in the laboratory with insecticides as indicated in experiments at College Station, Texas.

Treatment	Dosage[1]	Per Cent of Punctured Squares from which No Weevils Emerged		Per Cent of Punctured Squares from which the Weevils Died in the Adult Stage		Per Cent Reduction in Weevil Emerging from Bolls
		Insectary[2]	Field[3]	Insectary[2]	Field[3]	Insectary[4]
Dieldrin	.33	98.7	97.0	47	29	44.1
Heptachlor	.33	89.7	97.0	37	24	31.1
Chlordane	1.5	98.3	85.1	50	27	41.5
Aldrin	.33	94.8	92.5	39	22	45.4
Endrin	.33	87.1	88.8	38	17	53.2
BHC	.33	76.9	66.6	35	12	35.0
Toxaphene	3.0	92.3	48.1	32	13	26.0
EPN	.33	94.8	44.4	52	8	
Parathion	.33	70.0	25.9	23	11	
Methyl parathion	.33	38.4	18.5	27	7	
Minimum difference required for significance		13.2	7.8			11.7

[1] Pounds active ingredients per acre.
[2] Control of weevils developing in squares treated in the laboratory, and placed in cages located in the insectary during the emergence period.
[3] Control of weevils developing in squares treated in the laboratory and placed on the ground under cages located in the field during the emergence period.
[4] Control of weevils developing in bolls treated in the laboratory and placed in cages in the insectary during the emergence period.

table 4. The plats were sprayed at 5 day intervals using a high clearance sprayer developed for spraying small plats. A total of 200 punctured squares were picked from plants in plats receiving each treatment and also from check plats (50 squares from each replicate plat). The squares were gathered three times during the treatment period. A regular 5-day schedule of applications was maintained throughout the season. In order to be certain that the punctured squares collected had been sprayed at least one time, only those attached to treated plants were collected.

RESULTS.—*Laboratory tests.*—The results of the laboratory tests are shown in table 1. In general the chlorinated hydrocarbons were more toxic to weevils developing within the squares than the phosphorus compounds. Dieldrin, heptachlor, chlordane, aldrin, toxaphene and endrin gave a significantly higher percentage of mortality of weevils within the squares than either benzene hexachloride or the phosphorus compounds in tests where the treated squares were caged in the insectary. In most cases a higher mortality of weevils within the squares was recorded from the squares caged in the insectary than those caged in the field under normal weather conditions. In tests where the treated squares were caged in the field, dieldrin and heptachlor caused the highest percentages of mortality and were significantly more effective than any of the other compounds used except aldrin. If the larvae were affected by the poisons, they were killed when very small and could not be detected when the dried squares were examined. A high percentage of the weevils in the treated squares developed to adults but these adults either died or were paralyzed. Some of the paralyzed adults were taken out of the squares and placed on cotton plants but they did not recover. All of the chlorinated hydrocarbon insecticides used caused the weevils to die in the treated bolls but the mortality was not as great as it was within the squares.

Hanging square tests.—The same materials, table 3, were used in this series as were used in the laboratory tests described above. Dieldrin and aldrin were equally effective in controlling weevils within the squares hanging on the plants

Table 2.—The percentage mortality of weevils within hanging squares treated with insecticides as indicated at College Station, Texas.

TREATMENT	DOSAGE[1]	NUMBER PUNCTURED SQUARES	PER CENT OF PUNCTURED SQUARES FROM WHICH NO WEEVILS EMERGED
Dieldrin	.33	105	71
Aldrin	.33	91	61
Heptachlor	.33	106	46
Parathion	.33	106	39
Endrin	.33	121	29
BHC	.33	122	24
Toxaphene	3.0	134	21
EPN	.33	77	17
Methyl parathion	.33	110	7
Chlordane	1.5	115	0
Check	—	140	
Minimum difference required for significance			15

[1] Pounds active ingredient per acre.

Table 3.—Mortality of weevils within squares collected from plants sprayed with a power sprayer in a schedule of applications for weevil control, College Station, Texas.

TREATMENT	DOSAGE[1]	PER CENT OF PUNCTURED SQUARES FROM WHICH WEEVILS EMERGED	PER CENT OF PUNCTURED SQUARES FROM WHICH NO WEEVILS EMERGED
Field Test No. 1			
Check		64	
Toxaphene-DDT (2-1)	3.15	66	0
3-5[2]	.95	66	0
Endrin	.28	59	8
Field Test No. 2			
Check		44	0
Methyl parathion	.25	58	0
22/190[3]	.26	57	0
Toxaphene-DDT (2-1)	2.85	60	0
Field Test No. 3			
Check		60	
EPN	.78	51	18
Parathion	.25	36	40
Methyl parathion	.25	64	0
Field Test No. 4			
Check		46	
Dieldrin	.25	26	44
Heptachlor	.29	38	17
Aldrin	.29	46	0

[1] Pounds active ingredient per acre.
[2] 3% gamma BHC and 5% DDT.
[3] A phosphorus compound related to parathion.

when treated. Dieldrin gave better control than all the other materials used except aldrin. It will be noted that these data indicate a marked reduction in the control obtained from all the insecticides when compared to the laboratory treated squares. This reduction was probably due to the leaves on the plant preventing the spray from covering the squares as well as they were covered by directly spraying them under a cylinder as was done in the laboratory tests. Apparently the squares must be thoroughly covered by the spray to be effective against the weevil within the square.

Field tests.—The results of the field tests are shown in table 4. None of the insecticides affected the weevils developing within the squares from plants sprayed by a power sprayer in the usual manner. Several factors may account for the difference between the results of the hanging square tests and the field tests. The amount of active ingredient applied per acre in the field was slightly less than that applied in the former series of tests; however the dosages used were those currently recommended for boll weevil control. In the field the particles of spray may have been dispersed by the wind. In the hanging square tests a cylinder covered each plant while the spray was being applied and left over the plant for three minutes to allow all spray particles to settle. This cylinder eliminated any chance of the spray being dispersed by the wind and a better coverage of the squares was obtained.

SUMMARY.—Six chlorinated hydrocarbon insecticides and four phosphorus compounds were tested to determine their effect upon the developing weevils within the squares. In the laboratory experiments the insecticides varied in their toxicity to the developing weevils. In general, the chlorinated hydrocarbons produced a higher percentage of mortality than the phosphorus compounds. A higher percentage of weevils within the treated squares either died in the adult stage or were paralyzed.

The insecticides in the hanging square tests gave a marked reduction in control in comparison with the laboratory tests. This was probably because the leaves prevented the spray from adequately covering the squares.

When the insecticides were used in the field at recommended dosages for the control of adult boll weevils, there was apparently no mortality or paralysis of the developing forms.

LITERATURE CITED

Gaines, R. C. and A. L. Scales. 1948. Effectiveness of insecticides on the boll weevil in cotton squares. JOUR. ECON. ENT. **41**(3): 519.

Rainwater, C. F. 1947. Some insecticides causing boll weevil mortality inside of punctured cotton squares. JOUR. ECON. ENT. **40**(6): 923.

Insecticidally Treated Seed for Wireworm Control[1,2]

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The simplicity of treating seed with a poison as a means of killing insect pests of seed in the soil has appealed to growers as an easy and economical method of control. With this in view, the author has conducted laboratory and field tests for the control of the wireworm, *Melanotus communis* (Gyll.), one of the more serious insect pests attacking field corn in eastern North Carolina. This paper is a review of the materials used in these tests as well as a short review of some of the literature pertinent to this subject.

A number of materials have been used as seed treatments for wireworm control in the past 50 or more years without great success (Thomas 1930, 1940). For the most part these early trials were conducted with various arsenicals, mercurial, and other inorganic compounds which operated chiefly as stomach poisons or repellents. Probably one of the reasons for the failure of some of these compounds is that wireworms are capable of rejecting

[1] Contribution from the Entomology Department. Published with the approval of the director as Paper No. 460 of the Journal Series.

[2] Statistical analyses in this paper performed by Robert J. Monroe of the Institute of Statistics, N. C. State College.

some of these materials, as Woodworth (1938) has pointed out.

The development of new synthetic hydro-carbon insecticides with a greater degree of toxicity to insects than the old inorganic materials has spurred research in the use of insecticides as seed coatings for the control of subterranean pests.

A comprehensive review of seed coating materials and methods for wireworm control is given by Lange and co-workers (1949). Lindane was the most promising material used in the laboratory tests, surpassing parathion, benzene hexachloride, aldrin, dieldrin, DDT and chlordane. The species most susceptible to lindane was *Aeolus* sp., followed by *Limonius canus* Lec., *L. californicus* (Mann.), and *Anchastus* sp. Two other species readily susceptible to lindane were *Limonius clypeatus* Mots. and *Melanotus oregonensis* (Lec.).

Parathion has been found toxic to a number of species of wireworms. Dogger & Lilly (1949) reported parathion to be highly toxic to wireworms in Wisconsin. The following species were used by them in small laboratory tests: *Melanotus communis* (Gyll.), *Dalopius pallidus* Brown, and *Agriotes mancus* (Say). Of these species, they report *M. communis* as being the most common in the field. Lindane was less toxic than parathion. Chlordane was ineffective in these tests. In all cases, treatment of seed was made with 50 per cent dust at 4 and 8 ounces per bushel.

A number of states now recommend seed treatments for the control of various soil pests. A brief summary of these recommendations has been prepared by Fletcher (1952).

ADVANTAGES OF COATED SEED.—There are numerous advantages in using insecticidally coated seed as a means of controlling wireworms. There probably is no more economical method of treatment. As little as 2 ounces of insecticide may be used per bushel of seed, and such treatment may be seemingly economical where wireworm infestations are not heavy. Furthermore, the small amounts of insecticide used per acre do not present the residue and off-flavor problems that other methods of treatment may. However, as Leach and co-workers (1950) have pointed out, treatment of seed does not necessarily completely control wireworms.

An attempt to verify some of these apparent advantages was made in laboratory trials conducted in Raleigh and in field trials conducted in Hyde County, 170 miles east of Raleigh, where wireworms seriously damaged corn grown in peat muck type of soil. The remainder of this paper is a summary of these seed coating tests.

LABORATORY TRIALS.—Seed coating trials in the laboratory consisted of treating corn or oats with different insecticidal formulations. The corn varieties used were those commonly grown in eastern North Carolina where wireworms are a problem. The wireworm species used was *Melanotus communis* (Gyll.), which is the most common species of economic importance in this area.

METHOD OF TREATMENT.—The principal method of treating corn consisted of first moistening the seed with water or with a sticker[1] and then adding the insecticide powder to the seed and mixing it until an even coverage of the seed was obtained. In the treatment of oats with wettable powder concentrates, no water nor sticker was used. The wettable powder insecticide was simply mixed with the oats. Endrin diluted to the proper concentration was used on oats as an emulsion concentrate.

Treated seeds were planted in sterilized peat muck soil from wireworm infested fields of eastern North Carolina. Two types of containers were used for planting, (1) a 3-ounce size pill box and (2) a No. 10 tin can, 7 inches deep and 6 inches in diameter. With the exception of one test, all cans were maintained at laboratory temperatures, which averaged about 74° F. The exception consisted of a test at 60° F.

Examinations of test cans were made every day to observe any wireworms that had come to the surface of the soil and to check on plant growth. Germination of seed at laboratory temperatures was rapid. Records of plant growth and wireworm activity on the surface of the soil were made daily for 8 to 12 days after planting, when usually plants had reached a height of 6 to 7 inches when a final examination of each can was made. In the final examination, the height of the plants, the wireworm injury and the condition of the wireworms was noted.

[1] A 5 per cent solution of 15 c.p.s. Methocel, supplied by Dow Chemical Co. of Midland, Michigan.

DESCRIPTION OF TESTS.—Laboratory tests were conducted with treated corn and oats. For ease in reference and description, these tests are herein listed numerically as they were performed in the laboratory.

Test 1 consisted of preliminary trials with different formulations of chlordane. The purpose of this test was to check on the relative efficiency of different formulations of chlordane, with or without a sticker, in adhering to and covering the seed. The formulations used included (a) 5 per cent dust, (b) 50 per cent wettable powder and (c) 75 per cent emulsion concentrate. This test is summarized in table 1. No wireworms were used in this test.

Test 2 consisted of trials with three of the chlordane combinations tested in the first preliminary test. These combinations were as follows: (a) 5 per cent dust at 15 grams per 200 grams of seed with 15 ml. of sticker, (b) 2 grams of 50 per cent wettable powder per 200 grams of seed with 30 ml. of sticker, and (c) 2.6 grams of 75 per cent emulsion concentrate with 27 ml. of sticker per 400 grams of seed. In this test five No. 10 cans were used for each treatment. Each can contained five treated seeds and 10 matured wireworms averaging 30 mm. long. The results of this test are summarized in table 2.

Test 3 was similar to test 2 in that the same chlordane formulations were used, but smaller wireworms, 15 to 18 mm. long, were used. Furthermore, only five wireworms were used in each can. The results of this test are summarized in table 2, also.

In the first three tests, the sticker and the insecticide were mixed with the seed by stirring with a spatula. In test 4, the sticker was mixed with the seed as in the first three tests but the insecticide was then added and further mixing was done mechanically for 3.5 minutes by a paint reconditioning machine.

Test 4 consisted of comparison tests with nine different insecticide formulations used in 17 different treatments. In one series of treatments, a commercial sticker was used. In another series, the seed was pre-moistened with water but no sticker was used. Trials were conducted in No. 10 tins with five wireworms and five seeds per can. Each treatment was replicated five times. Seeds treated with sticker were used in test 4. Germination tests of both lots of treated seed were run at 1 month and again at 4 months after treatment. The results of test 4 are presented in tables 3, 4 and 5.

Test 5 was conducted with the same formulations as in test 4. However, in test 5, wireworms were confined in 3-ounce pill boxes instead of the No. 10 tins. Each pill box contained one seed and one full grown wireworm. The boxes were maintained at a temperature of 60° F. instead of the usual laboratory temperature which averaged about 74° F. The results of this test are summarized in table 3 under the column headed "At 60° F."

The three remaining laboratory tests were with treated oats. No 10 tins were, used in test 6 with five wireworms and 10 seeds per can. Each treatment was replicated five times.

In test 7, 3-ounce pill boxes were used with two seeds and two wireworms per box. Each treatment was replicated 4 times.

The 3-ounce pill boxes were used in test 8 with one seed and one wireworm in each box. Each treatment was replicated 10 times.

The results of the seed-coating trials with treated oats are presented in table 7.

FIELD TESTS.—Several of the formulations tried in the laboratory in 1951 for treating corn were tested later in Hyde County in small replicated field tests. Each coated seed trial was part of a larger test in which two other basic methods of treatment were tried. In Method "A" (the "broadcast" method) the entire soil surface was treated at 1 week before planting and then disced in to a depth of 4 inches. In Method "B", the seed was coated with the insecticide. In Method "C", the insecticide was mixed with the fertilizer and applied to the furrow just before planting. Table 8 lists the different insecticides and methods used in these field trials. The results of these trials are presented in table 9.

Widespread interest in the use of seed-coating prompted a number of growers in the vicinity of the field trials to use treated seed on their farms during the 1951 season. In all cases, the insecticide used was 25 per cent lindane wettable powder at the rate of 1 gram to 200 grams of corn planted at the rate of 4.5 kilograms (10 pounds) of seed per acre.

Lindane-treated corn seed was used in

Table 1.—Preliminary seed coating trials on corn with different formulations of chlordane to check on adherence and effect on germination.

FORMULATION	AMOUNT USED (GM.)	COATING MATERIAL	AMT. OF SEED (GRAMS)	APPEARANCE OF SEED COATING AFTER MIXING	PER CENT GERMINATION 5 MONTHS AFTER TREATMENT
5% dust	15	15 ml. sticker[1] containing 15% glycerine	200	Fairly rough coat but not flaking as when glycerine was not used	82[2]
	15	15 ml. sticker	200	Rough coat, some flaking	
	30	20 ml. sticker	200	Rough—some flaking	
50% wettable powder	2	Moistened slightly with water	250	Well coated, some flaking	71
	2	10 ml. sticker containing 15% glycerine.	200	Fairly even coating	
	2	20 ml. sticker	200	Fairly even coating	92
	2	None	250	Not smooth, flaking	
	5	Moistened with water slightly	250	Well coated, some flaking	78
75% emulsion concentrate	1.6	10 ml. sticker containing 15% glycerine	200	Even, waxy coat	
	2.6	27 ml. sticker	400	Even, waxy coat	86

[1] Sticker used was a 5% solution of 15 c.p.s. Methocel, supplied by the Dow Chemical Co., Midland, Michigan.
[2] Check lots of corn, not treated, had a germination percentage of 92 to 96%.

grower trials on 20 farms and occupied approximately 110 acres. Observations on the condition of stand in each field were made at 4 weeks after planting. The results of these observations are discussed later in this paper.

RESULTS OF LABORATORY SEED-COATING TRIALS.—In all laboratory tests conducted with wireworms, two criteria of control were used—kill of wireworms and injury to seed by wireworms. In some cases the seed injury was further classified into two categories: (1) penetration of seed, (2) penetration of stem.

The statistical analysis made use of the X^2 statistic. In some cases X^2 values were calculated on sub-sets of data further to delineate the groups of effective chemicals or of effective formulations.

PRELIMINARY TRIALS.—Results of test 1 presented in table 1, indicated that more than 15 grams of 5 per cent chlordane

Table 2.—Preliminary laboratory tests with corn seed treated with different chlordane formulations for control of wireworms of two different sizes.

	MATERIAL	AMOUNT OF MATERIALS USED			PER CENT OF SEED PENETRATED BY WWS. AFTER 8 DAYS	PER CENT OF WIREWORMS DEAD AFTER 8 DAYS[1]
		Insecticide (Grams)	Corn (Grams)	Sticker (Ml.)		
Large wireworms	5% chlordane dust	15	200	15	52	10
	50% chlordane wettable powder	2	200	30	8	17
	75% chlordane emulsion concentrate	2.6	400	27	22	16
	Check—untreated	0	200	0	84	0
					$\chi_3^2=70.3$, $P<.001$	$\chi_3^2=21.1$, $P=.001$
			Omitting check		$\chi_2^2=25.6$, $P<.001$	$\chi_2^2=5.3$, $P=.07$
Small wireworms	5% chlordane dust	15	200	15	8	25
	50% chlordane w. p.	2	200	30	4	39
	75% chlordane e.c.	2.6	400	27	8	29
	Check—untreated	0	200	0	68	0
			Omitting check		$\chi_2^2=3.35$, $P=.19$	$\chi_2^2=0.42$, $P=.80$

[1] Total of all replicates. 50 wireworms per treatment in the tests with large wireworms and 25 wireworms per treatment in the tests with small wireworms.

Table 3.—Percentage kill of wireworms in laboratory tests with different materials as seed coatings on corn, and germination rates.

Insecticides[1]	Grams of Insecticide per 450 Grams of Seed	Test No. 4 At Lab. temp. 74° F.		Test No. 5 At 60° F.		Percentage of Germination			
						Seed Treated With Sticker		Seed Pre-Moistened With Water Only	
						Time After Treatment		Time After Treatment	
		Per Cent Kill[2]	Per Cent of Seed Inj. by Wireworms	Per Cent Kill[3]	Per Cent of Seed Inj. by Wireworms	1 Month	4 Months	1 Month	4 Months
15% parathion	4.56	21	0	60	0	95	83	90	87
25% lindane	2.3	38	0	44	0	90	91	92	93
75% lindane	0.614	52	0	60	0	90	87	90	92
50% DDT	4.56	0	28	30	30	96	93	94	95
75% DDT	4.56	8	32	10	10	94	89	98	93
50% chlordane	4.56	17	0	40	10	97	90	95	97
25% heptachlor	4.56	54	0	60	0	94	89	95	93
25% heptachlor	2.28	37	0			97	98	94	98
25% aldrin	4.56	48	0			98	96	97	97
25% aldrin	2.28	75	0			96	98	97	97
25% aldrin	0.566	30	0	30	0	95	94	93	95
25% dieldrin	4.56	52	0			97	97	100	99
25% dieldrin	2.28	33	0			94	98	99	98
25% dieldrin	0.566	46	0	40	0	98	92	91	87
50% 2-nitro-1, 1-bis (p-chlorophenyl) propane	4.56	8	68	10	0	92	85	93	99
50% 2-nitor-1, 1-bis (p-chlorophenyl) butane	4.56	0	72	0	40	94	87	94	97
Inert clay diluent	4.56	0		0	10	93	92	93	88
Untreated check		0	80	0	30	95	94	96	91

[1] Wettable powders, supplied by the following concerns: parathion, American Cyanamid Co., lindane, California Spray-Chemical Corp.; chlordane and heptachlor, Velsicol Corp., aldrin and dieldrin, Julius Hyman Co.; 2-nitro-1, 1-bis (p-chlophenyl) butane and 2-nitro-1, 1-bis (p-chlorophenyl) propane, Commercial Solvents Corp.

[2] based on a total of 25 wireworms in each test (5 wireworms in each of 5 replicates).

[3] Based on a total of 10 wireworms in each test (10 replicates with 1 wireworm in each replicate).

dust per 200 grams of seed did not make a satisfactory coating because of the excessive flaking of dust. Wettable powder with sticker made a good seed coat. Addition of glycerine to the sticker seemed to improve the coating slightly in that the material did not flake quite so readily as when no glycerine was added. Wettable powder at 1 gram per 100 grams of seed gave good coverage but the coating was rough. Good coverage with 2 grams of 50 per cent wettable powder and no sticker was obtained when the seed was slightly moistened with water prior to the mixing with insecticide. An uneven coating was obtained when the seed was not moistened.

Germination tests performed 5 months after seed treatment showed a variable rate of germination—from 71 to 92 per cent. Untreated checks tested for germination at the same time showed a germination rate of 92 to 96 per cent.

Three of the formulations tried in test 1 were used in test 2 and 3 against two different sizes of wireworms. Test 2 and 3 are summarized in table 2.

Differences among treatments show up more sharply in test 2 with the large wireworms than they do in test 3 with the small wireworms. This sensitivity can be attributed to two factors—(1) there were more wireworms in test 2, and (2) the large worms formed a more severe test for the chemicals and were capable of inflicting more damage to the seed.

The 50 per cent chlordane wettable powder was the most effective of the three formulations used, based on the percentage of wireworms killed and on the protection afforded to seeds against penetration by wireworms.

None of the materials listed in table 2 seemed to have had any serious deleterious effect on seed germination and seedling emergence. In the tests with large wireworms the effect of the insecticide on germination and emergence was graded as slight to moderate as indicated by the delay in emergence and the condition of the stem when the plants were examined at the termination of the test 8 days after planting. In the tests with small wireworms the effects of the insecticide were not as noticeable as in the other test. It may have been that some of the supposed action of the insecticide in the first test was, instead, the result of wireworm attack. In neither series of tests was there any failure of germination that could be ascribed to the action of the insecticide upon the seed.

Test 4, seed-coating trials with 17 different treatments, is summarized in table

3. In judging the results of this test, both criteria of plant injury and kill of wireworms were used. From the standpoint of injury, it is quite apparent that the DDT formulations gave little protection and the nitro-paraffin compounds, 2-nitro-1, 1-bis (p-chlorophenyl) propane and 2-nitro-1, 1-bis (p-chlorophenyl) butane, gave no protection. All other compounds gave good protection.

The analysis of the kill data indicates about the same thing. A further analysis of the kill data of aldrin, dieldrin, heptachlor, and lindane combining the different rates of application of the same material shows that there was apparently little difference in the average killing power of the four compounds at the rates used. (See table 4).

Greater dosages of the same insecticide formulation in test 4 did not produce a correspondingly greater kill of wireworms. Aldrin 25 per cent at 2.28 grams per 200 grams of seed, had a much higher kill of wireworms, 75 per cent, than it did at a dosage of 4.56 grams, with a kill of 50 per cent. Dieldrin, 25 per cent, at 0.566 grams per 200 grams of seed had a kill of 46 per cent whereas at 2.28 grams, it had a kill of 33 per cent. A comparison of the formulations on the basis of kill data is presented in table 5.

In general the results of test 5 conducted in the pill boxes at 60° F. resembled those obtained in test 4 in No. 10 tins at a temperature of 74° F. However, at 60° F. the kill with parathion was 60 per cent whereas in test 4 at 74° F., the kill was 21 per cent.

The use of either criterion, kill or protection, indicates differences among the different treatments of test 5. In general, the protection given by any chemical was good if the kill was above 30 per cent. A grouping of treatments according to both criteria shows this relationship in table 6.

Germination tests of corn from test 4 were made at 1 month and at 4 months after treatment. The results of these tests, made by the paper towel ("rag-doll") method, are presented in table 3. Seven of the 17 treatments without the sticker had a lower germination percentage at 4 months than at 1 month after treatment. Where the sticker was used, 12 of the 17 treatments compared had a slightly lower germination rate at 4 months after treatment than at 1 month. The differences in the percentage of germination at these two periods after treatment are not significant.

In the germination tests made at 1 month after treatment, the seedlings had few secondary and tertiary rootlets. This may have been because of a lack of moisture rather than because of action of the insecticides. In the germination tests made later, at 4 months after treatment, many of the treatments had several plants with curved stems, some of them forming a complete loop. Germination tests conducted with seed in muck soil did not show any marked curving or looping of the stem nor was there any evident deleterious effect on seed germination in the soil germination tests.

TESTS WITH TREATED OATS.—The results of tests 6, 7 and 8 conducted with treated oats, are presented in table 7. These tests differed in the number of worms, seeds and size of containers used. The kill criterion was not sensitive enough to show the differences amongst the treatments here. Although the percentage of kill differed among the tests, the consistency of treatment differences from test to test was moderately good. The injury criterion was less consistent from test to test but it did demonstrate differences between treatments of the same test where seed penetration was the injury measure. Since test 6 had a ratio of two seeds for every wireworm used it is not possible to compare the results directly except to say that this technique seemed to give answers different from that used in tests 7, and 8 It is interesting that in test 6, seed penetration showed nothing but stem penetration indicated large treatment differences. In tests 7 and 8, the criteria were reversed—that is —stem penetration showed no differences while seed penetration did.

Where more seeds are used in the test container than there are wire-worms, it seems that the probability of any seed being hit is different than when the number of seeds and wireworms per container are equal.

There was no evidence of injury to seed by any of the treatments. However, in previous germination tests (not reported herein) it was noted that the Systox-treated[1] germination test had more

[1] 0-0-diethyl-0-2- (ethyl mercapto)-ethyl thiophosphate, 50 per cent on carbon supplied by the Geary Chemical Co.

Table 4.—Results of combinations of different rates of application of seed-coatings with aldrin, dieldrin, heptachlor, and lindane used in test 4.

INSECTICIDE	DOSAGES USED (GRAMS PER 450 GRAMS OF SEED)	PER CENT KILL[1]
25% Aldrin	0.566 2.28 4.56	48
25% Dieldrin	0.566 2.28 4.56	44
25% Heptachlor	2.28 4.56	46
75% Lindane 25% Lindane	0.614 2.3	45
	$x_3^2=1.14$, P.=0.78	

[1] Average for dosages used.

Table 5.—Comparison of rates and formulations of seed-coatings on corn in kill of wireworms in test 4.

INSECTICIDE	GRAMS USED PER 450 GRAMS OF SEED	PER CENT KILL OF WIREWORMS	
25% Aldrin	0.566 2.28 4.56	30 75 48	$X_1^2=9.48$, P=.009 Median rate has markedly greater kill
25% Dieldrin	0.566 0.28 4.56	46 33 52	$X_1^2=2.19$, P=.35 No difference
50% DDT 75% DDT	4.56 4.56	0 8	$X_1^2=0.15$ No difference
25% Heptachlor	2.28 4.56	37 54	$X_1^2=0.84$, P=0.35 No difference
25% Lindane 75% Lindane	2.3 0.614	38 52	$X_1^2=0.96$, P=0.33 No difference

curved stems and darker seeds than did untreated seed or seed treated with endrin. Lindane-treated seed produced some roots with a "rabbit-tail" appearance—that is—short fuzzy roots, two or three per seed, which never got longer than 0.5 to 1 inch. (A similar effect has been noted by the technicians in the seed testing laboratory in germination tests with wheat treated with a fungicide.) In the aldrin-treated germination test, stems were more curled and seed was brighter than in the Systox-treated seed germination test. No adverse effects of the treatment were noted on seeds grown in the pill boxes during the wireworm tests.

RESULTS OF FIELD TESTS WITH TREATED CORN.—Compared with the other two methods of treatment tried in the field (namely, "broadcast" soil application and fertilizer-insecticide mixtures), seed-coating afforded the least protection against wireworm attack. Records were made of plant and wireworm conditions at eight weekly intervals after planting

Table 6.—Relationship of kill of wireworms to plant injury based on results with treated seed in Test 5.

PER CENT KILL	MATERIAL USED	GRAMS USED PER 200 GRAMS OF SEED	PER CENT INJURY	MATERIAL USED	GRAMS USED PER 450 GRAMS OF SEED
40–60	15% parathion	4.56	0	15% parathion	4.56
	25% lindane	2.3		25% lindane	2.3
	75% lindane	0.614		75% lindane	0.614
	50% chlordane	4.56		25% heptachlor	4.56
	25% heptachlor	4.56		25% aldrin	0.566
	25% dieldrin	0.566		25% dieldrin	0.566
				50%, 2-nitro-1, 1-bis (p-chlorophenyl) propane	4.56
30	50% DDT	4.56	10	75% DDT	4.56
	25% Aldrin	0.566		50% chlordane	4.56
				Inert clay diluent	4.56
10	75% DDT	4.56	30	50% DDT	4.56
	50%, 2-nitro-1, 1-bis (p-chlorophenyl) propane	4.56		Untreated check	
0	50%, 2-nitro-1, 1-bis (p-chlorophenyl) butane	4.56	40–60	50%, 2-nitro-1, 1-bis (p-chlorophenyl) butane	4.56
	Inert clay diluent	4.56			
	Untreated check				

Table 7.—Laboratory tests with treated oats. Tests 6, 7, and 8.[1]

Treatment[2]	Per Cent Kill			Per Cent Injury					
				Test No. 6		Test no. 7		Test no. 8	
	Test no. 6	Test no. 7	Test no. 8	Seed	Stem	Seed	Stem	Seed	Stem
25% aldrin	4	0	30	6	4	0	0	0	0
25% chlordane	8	0	0	6	0	88	0	50	10
25% dieldrin	4	25	10	4	14	25	0	10	0
0.05% endrin	—	—	14	—	—	—	—	60	20
25% heptachlor	0	0	20	4	10	25	0	40	0
25% lindane	16	0	29	2	2	25	13	20	0
50% 0,0-diethyl-0-2-(ethylmercapto)-ethyl thiophosphate	—	—	11	—	—	—	—	40	20
Untreated check	0	13	10	10	18	50	13	80	40
χ^2	6.16	6.61	5.57	3.70	17.4	15.8	4.4	19.5	—
P	.30	.27	.35	.59	.004	.08	.50	.002	—

[1] Test No. 6, 5 wireworms and 10 seeds per No. 10 tin, 5 replicates per treatment.
Test No. 7, 2 wireworms and 2 seeds per 3 oz. pill box, 4 replicates per treatment.
Test No. 8, 1 wireworm and 1 seed per 3 oz. pill box, 10 replicates per treatment.
[2] Dilute endrin, formulated from a 6.5% emulsion concentrate applied at rate of 1 ml. of 0.05% solution to 50 grams of seed. Other materials applied at rate of 1 gram of powder to 250 grams of seed.

but only the records of the fourth to sixth week after planting were used in evaluating the results. This period of the fourth to sixth week after planting was the time of the greatest wireworm activity and damage to corn. The materials and methods used in the field tests are listed in table 8. A summary of the results of these field treatments is presented in table 9.

FARMER TRIALS WITH TREATED CORN SEED FOR WIREWORM CONTROL.—A survey was conducted in the spring of 1951 to determine the effectiveness of seed-coating with lindane for the control of wireworms attacking corn. In all cases, the formulation used was 25 per cent wettable powder lindane at the rate of 1 gram to 200 grams of corn seeded at the rate of 4.5 kilograms (10 lbs.) per acre.

Lindane-treated seed was used on 20 farms on approximately 110 acres of corn. Four weeks after planting, 77 acres of the 110 acres treated showed wireworm damage, in some instances as much as 70 per cent of the stand had been damaged. Forty-eight of the 77 acres damaged were plowed up and replanted to other crops. A survey of fields planted with untreated corn showed that a total of 373 acres out of 600 acres on 80 farms were damaged, in some cases the entire stand was killed. Of the 373 acres where corn was damaged by wireworms, 222 acres were plowed under and replanted to other crops.

DISCUSSION.—Laboratory tests with seed treatments showed some promise of this method as a means of controlling wireworms attacking corn. One of the laboratory seed coating trials with aldrin, for example, had a killed of 75 per cent of the wireworms within 8 days after treatment and in this time there was no pene-

Table 8.—Methods and insecticides used in field tests for control of wireworms attacking corn in Hyde Co., N. C.

Materials	Method A, Broadcast	Method B, Seed Coating		Method C Fertilizer Insecticide Mixture
	Lbs. of toxicant per acre	Concentration	Grams of insecticide used on 4.5 kgs. of seed per acre	Lbs. of actual toxicant per acre
Aldrin	1	25%	22.8	1
Chlordane	5	50%	45.6	5
Dieldrin	2	25%	45.6	2
Heptachlor	2	25%	45.6	2
Lindane	2	25%	22.8	2
Check	0	0		fertilizer only

Table 9.—Mean number of healthy plants in 12 lineal feet of row in the 3-week period at 4 to 6 weeks after planting in field tests for wireworm control in corn.[1]

By Materials		By Method	
Lindane	17.21	A—(Broadcast)	16.06
Heptachlor	16.96	B—(Seed Coated)	14.52
Dieldrin	16.94	C—(Fert.-Ins. Mixture)	16.50
Aldrin	16.55	Check	10.92
Chlordane	13.73		
Check	10.92		
L.S.D. (5%)	2.83	L.S.D. (5%)	1.64

[1] Perfect stand = 20 plants in 12 feet of row.

tration of seed by the wireworms (table 3, 25 per cent aldrin at 2.28 grams per 450 grams). It should be remembered, however, that these laboratory results were based on only five replications, each replication consisting of a gallon-size tin of soil containing five treated seeds and five full-grown wireworms. Under such conditions, the number of times that any one seed might be attacked would be less than it could have been under field conditions, where any number of wireworms might attack the same seed. This, of course, would be particularly true under conditions of heavy populations of wireworms.

In the field tests, the seed-coating method was not as effective as the soil "broadcast" or insecticide-fertilizer mixtures (table 9—"By Method"). The field tests were conducted in heavily infested land. It may be that seed coating would have shown up better in areas less heavily infested by wireworms.

Another factor which mitigated against the use of seed-coatings in the field trials as a successful means of control, is the feeding habits of the wireworm involved, *Melanotus communis* (Gyll.). Individuals of this species feed on the seed up to the time that corn is 4 to 6 inches high. Then they gradually begin to feed on the stem and roots up to the time that corn is 24 inches tall.

SUMMARY.—Preliminary laboratory trials with chlordane as a seed coating on corn showed that a 50 per cent wettable powder formulation was more effective against the wireworm *Melantus communis* (Gyll.) than was a 5 per cent dust or a 75 per cent emulsion concentrate. Further laboratory trials showed that aldrin, heptachlor and dieldrin at 25 per cent wettable powders and lindane as a 75 per cent wettable powder were effective as seed coatings in killing wireworms and protecting corn from insect attack. The heavier applications did not necessarily produce a greater kill of wireworms than did lighter applications. Aldrin, 25 per cent wettable powder at 2.28 grams per 450 grams of seed produced a kill of 75 per cent of the wireworms and at 4.56 grams, it resulted in a kill of 50 per cent. Wireworms held at a soil temperature of 60° F. responded to the seed-coating method of treatment in about the same manner as they did in soil kept at 74° F., except in the case of 15 per cent wettable powder parathion. With this material, a kill of 21 per cent was obtained at 74° F. and a kill of 60 per cent at 60° F. Results of field tests with treated corn were not as good as they were in the laboratory tests.

In three different-sized laboratory tests with treated oats the kill criterion was not sensitive enough to show any differences amongst the treatments. A better measure of effectiveness was obtained by using the injury criterion for treatments within a test.

In replicated field tests with corn, the seed-coating method was the poorest of three different methods of treatment.

A survey of 110 acres of corn planted with lindane-treated seed and of 600 acres planted with untreated seed showed no great difference in favor of the treated seed as regards amount of damage to the stand of corn by wireworms. Heavy wireworm populations and extensive feeding on the roots and underground portion of the stem are probably the chief reasons for the poor showing of the seed-coating method of treatment.

LITERATURE CITED

Dogger, J. R. and J. H. Lilly. 1949. Seed treatment as a means of reducing wireworm damage to corn. JOUR. ECON. ENT. 42(4): 663–5.

Fletcher, Fred. 1952. Insecticides as seed treatments for the control of soil pests. Down to Earth (Dow Chemical Co.) 8(1): 16–9.

Lange, W. H., Jr., E. C. Carlson, L. D. Leach. 1949. Seed treatments for wireworm control with particular reference to the use of lindane. JOUR. ECON. ENT. 42(6): 942–55.

Lange, W. H., Jr., L. D. Leach and E. C. Carlson. 1950. Lindane for wireworm control. Calif. Agr. 4(1): 5–6.

Thomas, C. A. 1930. A review of research on the control of wireworms. Pa. Agr. Expt. Sta., Bul. 259.

Thomas, C. A. 1940. The biology and control of wireworms. A review of the literature. Pa. Agr. Expt. Sta., Bul. 392.

Woodworth, Charles E. 1938. The reactions of wireworms to arsenicals. Jour. Agr. Res. 57(3): 229–38.

New Acaracides Against Mites Attacking Nursery Plants[1]

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The control of spider mites on plants growing in nurseries has not received as much attention as would be indicated from the amount of damage done. Many species of plants are regularly infested each year by spider mites. These infested and severely injured plants do not recover satisfactorily and rarely make as good a growth as uninjured plants. With the advent of many new materials for control of spider mites, work has been started to determine the efficiency of some of these materials in controlling spider mites and to determine their phytotoxicity on the wide variety of plants found in the nursery.

This report gives the results of some of these tests. The data have been summarized and condensed and in most cases the control is expressed as the percentage reduction of live mites found on foliage of treated plants as compared with the number of live mites found on check plots or unsprayed plants. The samples examined were large enough to give comparable results.

Spraying was done in the field with a 5-gallon bucket type of hand pump, a hydraulic sprayer giving pressures up to 400 pounds, or a mist sprayer. Sprays applied by the bucket pump and by the power hydraulic pump were usually used at the concentration recommended by the manufacturer and double the recommended concentration to determine their phytotoxicity. Applications made with the mist sprayer were usually 10 times the concentration recommended for hydraulic spraying.

Control of *Brevipalpus inornatus* (Banks) (1) on azaleas. A new kind of spider mite was found on field and greenhouse grown azaleas in one of the nurseries in northern New Jersey in 1946. This mite was identified at that time as belonging to the genus *Brevipalpus* and since then has been identified as *Brevipalpus inornatus* (Banks). It belongs to a group known as as the false spider mites. The small or young mites are a brilliant red becoming darker as they mature. They are compressed, with the legs extending outward from the body. The full grown mites are about 0.5 mm. in length. The eggs are bright red, oval, and laid in groups of 2 or 3 to a dozen or more on the surface of the leaves.

This species appears to be fairly widely distributed throughout the western, southern, and eastern parts of the United States and southeastern Canada. It has also been reported from Japan, Australia, Argentina, and Venezuela. It attacks a large number of plants, having been found on flowering shrubs, perennials, palms, ivy, chrysanthemum, and some weeds. On azaleas its feeding causes a loss of the green chlorophyll, resulting in a browning or bronzing of the foliage. Injured leaves drop off.

Azalea plants, variety Petrick, about 10 inches tall and set about 10 inches apart in raised benches, were infested with the false spider mite, *Brevipalpus inornatus*. Approximately 75 plants were used in each spray test. Sprays were applied with a bucket type spray pump. Divider boards were used between spray spray plots to prevent overlapping of the spray materials. Fifty leaves were examined for each plot at each examination period. Plants were sprayed July 29, examined August 6 and again on August 14. They were resprayed August 18 and reexamined August 28. Counts were made of the live eggs, young mites, mature mites, and dead mites. Table 1 gives only the average number of live mites per 50 leaves and the percentage reduction of the live mites on the sprayed leaves over the live mites on the check or unsprayed plants.

The materials used in the tests are as follows:

Ovotran WP, contains 50 per cent p-chlorophenyl p-chlorobenzene sulfonate.

Ovotran emulsion contains 20 per cent p-chlorophenyl p-chlorobenzene sulfonate.

Geigy 338 Acaracide, emulsion, contains 25 per cent 4,4′ -dichlorobenzilicacid ethyl ester. The Geigy Company Inc., New York, N. Y.

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology.

Table 1. Kill of *Brevipalpus inornatus* (Banks) on Azaleas, sprayed July 29.

Material	Dilution 100 Gals. Water	Per Cent Reduction Over Check		
		Aug. 6	Aug. 14 and 15	Resprayed Aug. 18 Examined Aug. 28
Ovatran 50% WP	1 lb.		100	
	2 lbs.	100	100	100
Ovatran 20% Em.	1 pt.		94	
	2 pts.	94	100	100
Geigy 338 25% Em.	1 pt.		100	
	2 pts.	100	100	100
Aramite 15% WP	1 lb.		99	
	2 lbs.	100	100	100
Malathon 50% Em.	1 pt.		60	
	2 pts.	52	86	10
Malathon 25% WP	2 lbs.		63	
	4 lbs.	29	92	20
Metacide 50% Em.	8 ozs.		57	
	16 ozs.	87	86	72
Dimite 25% Em.	1 pt.	100	100	100
	2 pts.		100	
EPN-300 27% WP	1 lb.		98	
	2 lbs.	83	99	90.8
OMPA 100%	3 ozs./acre	63	52	4.5
	4 ozs./acre	39	56	3.7
	6 ozs./acre	64	54	11.0
Penn. Salt NP 602 E 25	7.5 ozs./ 3 gals.	93	95	100
Systox 42% Em.	3 ozs. active	37	88	7.5
	4 ozs. active	56	78	11.5
	6 ozs. active	46	68	4.9
Chemite	1 qt.		98	
	2 qts.	100	100	100
Check-Ave. No. live mites per 50 leaves for 5 check plots		446	446	1655

Aramite WP, contains 15 per cent of 2-(p-tert-butyl phenoxy) isopropyl 2-chloroethyl sulfite. Naugatuck Chemical Company, Naugatuck, Connecticut.

Aramite emulsion, contains 2 pounds per gallon of 2-(p-tert-butyl phenoxy) isopropyl 2-chloroethyl sulfite. One-half pint of this formulation is equivalent to one pound of Aramite 15 W. Naugatuck Chemical Company.

Malathon is the common name for 0,0-dimethyl dithio phosphate of diethyl mercaptosuccinate. It was used as a 25 per cent wettable powder and a 50 per cent emulsion. It was obtained from the American Cyanamid Company, New York City, N. Y.

Metacide 50 per cent emulsion is the mixed esters of para nitrophenyl thiophosphonic acid and consists of a mixture of 25 per cent parathion and 75 per cent of the dimethyl analogue of parathion.

Dimite is an emulsion containing 25 per cent of di(p-chlorophenyl) methyl carbinol. It is manufactured by the Sherwin-Williams Company.

EPN-300 was available as a wettable powder containing 27 per cent of ethyl p-nitrophenyl thiobenzene phosphate. It was obtained from the Grasselli Chemical Department of the E. I. du Pont de Nemours & Company, Inc.

Chemite, contains 19.35 per cent p-chlorophenyl p-chlorobenzene sulfonate, 1.80 per cent rotenone and other cube resins, and 57.85 per cent solvent and emulsifier. It was obtained from the Chemical Insecticide Corporation, Brooklyn, New York.

Penn Salt, NP 602, E 25, is an experimental acaracide obtained from the Pennsylvania Salt Manufacturing Company, Philadelphia, Pa., and contained 25 per cent active principle. This was recommended at a dilution of one gallon to 50 gallons of water.

O.M.P.A. is a technical grade of octa-

Table 2. Kill of *Brevipalpus inornatus* (Banks) on Azaleas, Sprayed Aug. 13.

Materials and Dilution to 100 Gallons	Dilution 100 Gals. Water	First Exam. Aug. 23		Second Exam. Sept. 3	
		No. Mites/50 Leaves	Per Cent Reduction Over Check	No. Mites/50 Leaves	Per Cent Reduction Over Check
Ovatran 50% WP	2 lbs.	0	100	0	100
Ovatran 20% Em.	1 qt.	2	99.5	0	100
Geigy 338 25% Em.	1 qt.	0	100	0	100
Aramite 15% WP	2 lbs.	21	96.5	0	100
Malathon 50% Em.	1 qt.	39	93.5	88	85.8
Malathon 25% WP	4 lbs.	54	90.9	51	91.8
Dimite 25% Emul.	1 qt.	8	98.6	0	100
EPN-300 27% WP	2 lbs.	27	95.5	0	100
Chemite Em.	2 qts.	0	100	0	100
OMPA technical	4 ozs.	329	45	319	48.7
Systox 42% Em.	4 ozs.	512	14.2	541	13
Metacide 50% Em.	16 ozs.	21	96.5	37	94
Check No. 1		609		687	
Check No. 2		486		557	
Ave. Checks		597		622	

methylpyrophosphoramide. It was obtained from the Monsanto Chemical Company, St. Louis, Mo.

Systox is an emulsion containing 42 per cent 0,0,diethyl-0-2(ethyl mercapto)-ethyl thiophosphate plus emulsifier. It was obtained from the Dow Chemical Company.

A second test on new plants was started August 13. Plants were sprayed as previously explained. Leaves were collected for examination on August 23 and September 3, 1952. The data for these tests are given in Table 2.

The kill of the mite, *Brevipalpus inornatus*, was very good with Ovatran, Geigy 338, Aramite, Dimite, EPN-300 and Chemite. The kill with Malathon and Metacide was rather erratic. The Penn Salt NP 602 gave a good kill but the foliage was spotted due to the spray. OMPA and Systox gave very poor and erratic kill. None of the materials except the Penn Salt NP 602 caused any injury to the azalea plants.

Tests on the southern red mite, *Paratetranychus ilicis* McG., infesting *Ilex bullata*. Tests were made at the Bobbink and Atkins Nursery, Freehold, on *Ilex bullata* plants infested with the southern red mite. The plants were 8 to 10 inches tall, planted 12 inches apart in outdoor beds in the nursery. Approximately 50 plants were used in each spray block. The plants were thoroughly sprayed with a 5-gallon bucket type hand pump. The plants were sprayed June 9, and foliage was collected for examination on June 12 and 17. The data from these two collections are combined in table 3 and are expressed as the percentage reduction of live mites over the live mites found in the check plots.

Table 3.—Kill of *Paratetranychus ilicis* on *Ilex bullata*. Sprayed June 9. Total of counts June 12 and June 17.

Material	Dilution 100 Gals.	No. Live Mites	Per Cent Reduction Over Checks
Ovatran 50% WP	1 lb.	0	100
	2 lbs.	2	93
Ovatran 20% Em.	1 pt.	4	86
	2 pts.	3	89.6
Geigy 338 25% Em.	1 pt.	0	100
	2 pts.	0	100
Aramite 15% WP	1 lb.	0	100
	2 lbs.	2	93
Malathon 50% Em.	1 pt.	1	96.5
	2 pts.	0	100
Malathon 25% WP	2 lbs.	0	100
	4 lbs.	0	100
Metacide 50% Em.	8 ozs.	0	100
	16 ozs.	0	100
Dimite 25% Em.	1 pt.	1	96.5
	2 pts.	0	100
EPN-300 27% WP	1 lb.	0	100
	2 lbs.	0	100
Check No. 1		46	
Check No. 2		31	
Check No. 3		9	
Ave. of 3 checks		29	

45 leaves counted for each block. 15 in June 12 count and 30 in June 17 count.

The plants were examined several times during the summer. The control was good until about the middle of August when an infestation began to build up.

No injury occurred to the plants from any of the spray materials.

The following sprays were applied June 13.

Geigy 338 Acaracide 25 per cent emulsion was diluted 1 quart to 100 gallons of water and sprayed on *Ilex bullata* plants infested with the southern red mite and *Juniperus pfitzeriana* infested with the two-spotted spider mite. The spray was applied with a Bean 50 gallon estate sprayer.

An Ovotran 25 per cent emulsion diluted 1 pint to 100 gallons of water was applied to *Ilex bullata* and *Ilex crenata* infested with the southern red mite and to *Juniperus pfitzeriana*, *J. horizantalis*, and *J. smithi* infested with the two-spotted spider mite. Applications were made with the Bean estate sprayer.

Malathon 50 per cent emulsion was diluted 1 gallon to 100 gallons with water and applied with a Farquhar Iron Age Mist blower. The plants treated were *Ilex globra*, *Ilex rotundifolia* and *Ilex latifolia* infested with the southern red mite. Also *Juniperus arora*, *Juniperus* sp., *Juniperus pfitzeriana*, globe arborvitae, *Thuja occidentalis globosa*, and the American arborvitae, *Thuja occidentalis*, infested with the two-spotted spider mite.

The above sprayed plants were examined June 18 and again July 23. The spider mite control was excellent and there was no injury to any of the sprayed plants from the spray materials.

Several varieties of boxwood plants —*Buxus Hansworthi*, *B. sempervirens* (Maplewood), *B. sempervirens myrtifolia*, and *B. sempervirens suffruticosus* were

sprayed with a 25 per cent Aramite emulsion diluted 1 gallon to 100 gallons with water and applied with the Farquhar Iron Age Mist blower. This spraying was done in late August. The control was excellent and no injury to the plants developed.

SUMMARY.—The work reported in this paper as well as a considerable amount of spraying with the mist blower, using Aramite, Geigy 338 Acaracide and Malathon, applied for commercial control in the nursery and in which no counts of dead and live mites were made, showed that good control was obtained with the following materials: Ovotran, Aramite, Geigy 338, Dimite, Chemite and EPN-300 Spray applications by hydraulic sprayer or by mist blower usually gave good control for 5 or 6 weeks. Metacide and Malathon gave a good kill but were not quite as effective as the other materials.

These new miticides are more effective than TEPP and parathion which have been used for spider mite control for several years. Most of them have better egg kill and a longer residual action. Some of them do not destroy parasites or predators which feed upon the spider mites. They appear to be safe on the foliage of most nursery plants. They should materially assist the nurseryman in controlling spider mites infesting his plants.

LITERATURE CITED

Prichard, A. E. and E. W. Baker. 1951. The false spider mites of California (acarina: phytophipalpidae) University of Calif. Pub. in Entomology, Vol. 9, No. 1.

Persistence of DDT in Soils of the Area Infested by the Japanese Beetle[1]

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Entomologists, plantsmen, and manufacturers of insecticides are showing considerable interest in the persistence of DDT residues in soil. There is the qusetion whether its repeated use on crops might result in the accumulation of harmful residues in the soils. On the other hand, it is important to know how long a treatment of the soil may be effective in controlling the Japanese beetle, *Popillia japonica* Newm., the European chafer, *Amphimallon majalis* (Razoum), or other soil-infesting insects. Experimental results by Schread (1949), Fleming (1950), Fleming & Maines (1947), Fleming & Hawley (1950), and Polivka (1947, 1952) have demonstrated that residues of DDT remain insecticidally active for several years, but little information is available on the amounts present at various intervals after treatment.

Cullinan (1949) reported that DDT was stable in soil. Smith (1948) demonstrated that DDT was stable in acid and alkaline soils, and after 18 months recovered 98 per cent of the DDT applied. Foster (1951) found no significant loss of DDT in four cultivated soils in cold frames during 4 years. Fleming, *et al.* (1951–a) found that one-third of the DDT applied as a surface treatment to established turf remained after 6 years.

An investigation was begun at Moorestown, N. J., in 1943 to determine the amount of DDT in representative soils of the Japanese beetle area at various intervals after treatment.

COLLECTION OF SOILS.—Most of the soils were obtained in areas that had been cleared and were under cultivation; some of them came from wooded areas or uncultivated fields. Each type was collected from an area in which it was abundant. For each sample the A horizon, or top layer of soil, was removed and passed through a 1/4-mesh screen to remove stones and debris. A total of 84 mineral soils were collected: 15 from Connecticut, 12 from Massachusetts, 28 from New

[1] Presented at the meeting of the American Association of Economic Entomologists at Philadelphia, Pa., December 15–18, 1952.

[2] The soils used in this study were obtained through the cooperation of the agricultural experiment stations of Connecticut, Massachusetts, New York, Ohio, and Rhode Island, and also of the Northeastern Region of the Bureau. L. W. Coles, C. A. Perkins, and H. W. Strabel, of the Bureau's Japanese Beetle Laboratory, assisted in this investigation.

Jersey, 2 from New York, 9 from North Carolina, 15 from Ohio, and 3 from Rhode Island. In addition, a muck was obtained from Virginia.

EXPERIMENTAL PROCEDURE.—DDT was intimately mixed with each type of soil in a rotating drum at the rate of 1.04 grams per cubic foot. This procedure was equivalent to applying 25 pounds per acre and mixing it with the upper 3 inches of soil. In 1943, but not in later years, DDT was applied also at the rate of 50 pounds per acre. A 1-per cent dust was used to facilitate mixing the toxicant with the soil. Each treated soil was placed in three trays 18 inches square and 4 inches deep, and seeded with redtop. The soils were maintained in a moist, friable condition in the laboratory during the testing period from October to March; during the remainder of the year they were exposed in clay pots to weathering in the field. The cycle of testing and weathering has been repeated annually during the course of this investigation.

Although the treated soils were not exposed to weathering throughout the year, it is believed that any change in the concentration of DDT would approximate closely that with the toxicant incorporated with soil in the field. There was little change in the concentration of DDT in soil in the field during the cold part of the year; most of the reduction in concentration occurred during the late spring and summer when the soils were exposed to weathering.

Fleming *et al.* (1951) found that residual DDT in soil can be determined by chemical analysis or by bioassay with third-instar larvae of *Popillia* or with adults of *Macrocentrus ancylivorus* Rohwer. Within the range of concentrations encountered in this investigation, the DDT can be determined by any of these methods within 2.5 pounds per acre, or 1 part of DDT in 400,000 parts of soil. The determinations of DDT in these soils were made by bioassay with *Popillia* larvae, 450,000 larvae being used.

For these bioassays standards of insecticidal action were prepared by mixing DDT with soil at rates ranging from 5 to 25 pounds per acre. Each freshly mixed standard was placed in three to five trays. Fifty, third-instar, larvae were introduced into each tray and in trays of the test soils. The trays were then placed in a room maintained at approximately 80° F. At weekly intervals the number of larvae surviving in each treated and untreated soil was determined, no differentiation being made between the apparently moribund and the normal survivors. During the testing season each tray was infested 2 to 5 times, depending upon the supply of larvae available. After an exposure of 2 weeks the survival in a test soil was compared with that in a known amount of DDT, and by interpolation the amount of DDT in the test soil was determined.

AVERAGE RESIDUAL DDT.—The average residual DDT in the 85 soils treated with DDT at the rate of 25 pounds per 3-inch acre was as follows:

After Indicated Years	*Per Cent*
1	97
2	90
3	79
4	64
6	56
8	44

The curve was of the sigmoid type, showing that the loss of DDT took place slowly for about 2 years, then rapidly, then more slowly again. In the 28 soils to which 50 pounds of DDT per acre had been applied, 55 per cent remained after 8 years. Thus at both levels of treatment approximately half the DDT was lost in 8 years.

When mixed with soil as in these experiments, DDT was lost at a slower rate than when applied as a top-dressing to establish turf. In the turf experiments (Fleming *et al.* 1951-a) 98 per cent remained after 1 year, 85 per cent after 2 years, 53 per cent after 4 years, 39 per cent after 5 years, and 35 per cent after 6 years.

The persistence of DDT in soil, however, is modified by many factors other than the method of application, such as the organic content and texture of the soil, cultural practices, and the environmental conditions.

EFFECT OF SOIL SERIES.—A series designation is given by pedologists to all soils whose characteristics, other than the texture of the surface layer, are uniform in all respects. The soils of the different series were classified according to the amount of DDT remaining after 3 years as follows:

Table 1.—Persistence of DDT in different series of soils.

GROUP	NUMBER OF SOILS	POUNDS PER ACRE AFTER INDICATED MONTHS						
		0–4	12–16	24–28	36–40	48–52	72–76	96–100
1	27	25.0	25.0	24.9	24.5	22.4	18.0	13.2
2	30	25.0	24.7	23.4	20.7	17.7	13.1	10.4
3	20	25.0	24.1	20.7	16.5	12.6	8.8	6.2
4	7	25.0	22.4	16.4	8.6	6.3	—	—
5	1	23.0	14.0	9.5	6.0	3.5	—	—

Group 1, 90–100 per cent.—Caneadea, Cecil, Chester, Chicopee, Davidson, Dunellen, Durham, Gloucester, Hadley, Hartford, Helena, Iredell, Lakewood, Marlboro, Merrimac, Newfield, Painesville, Penwood, St. Johns, Sassafras, Whippany, and Wooster.

Group 2, 75–90 percent.—Agawam, Berks, Brookston, Charlton, Collington, Colts Neck, Croton, Dover, Elkton, Georgeville, Hagerstown, Keyport, Lansdale, Mahoning, Ontario, Penn, Portsmouth, Shrewsbury, Washington, Wethersfield, and Woodstown.

Group 3, 50–75 percent.—Appling, Ashe, Bernardston, Berrien, Bridgehampton, Brookfield, Cheshire, Mentor, Narragansett, Ondawa, Paxton, Pittsfield, Reynolds, Suffield, Toledo, Wauseon, Wingdale, and Woodbridge.

Group 4, 25–50 percent.—Chenango, Coloma, Essex, Lorain, Menlo, and Plymouth.

Group 5, less than 25 per cent.—Muck.

The average residual DDT in each group of soils was determined at intervals and is summarized in table 1.

In group 1, which included about 32 per cent of the soils, 53 per cent of the DDT remained after 8 years; in group 2, with 35 per cent of the soils, 42 per cent remained; and in group 3, with 24 per cent of the soils, 25 per cent of the DDT remained. In two-thirds of the soils about half the DDT was present after 8 years; in nine-tenths of the soils one-fourth or more of the toxicant was found after this period. The indications are that DDT will persist in many of these soils for several more years. However, some soils, particularly those of the Chenango, Coloma, Essex, Lorain, Menlo, and Plymouth series, and muck, have characteristics that significantly reduce the longevity of the toxicant.

REGIONAL EFFECT.—The 84 mineral soils were grouped according to their origin to determine whether the region had any effect on the persistence. The series of soils in these groups were as follows:

Southern New England. Agawam, Bernardston, Bridgehampton, Brookfield, Charlton, Cheshire, Chicopee, Coloma, Dover, Essex, Gloucester, Hadley, Hartford, Menlo, Merrimac, Narragansett, Newfield, Ondawa, Paxton, Penwood, Plymouth, Suffield, Wethersfield, Whippany, Wingdale, and Woodbridge.

New York. Ontario and Pittsfield.

Northeastern Ohio. Brookston, Caneadea, Chenango, Lorain, Mahoning, Mentor, Painesville, Reynolds, Toledo, Wauseon, and Wooster.

New Jersey. Berks, Chester, Collington, Colts Neck, Croton, Dunellen, Elkton, Gloucester, Hagerstown, Keyport, Lakewood, Landsale, Merrimac, Penn, Portsmouth, Sassafras, Shrewsbury, St. Johns, Washington, Wethersfield, and Woodstown.

North Carolina. Appling, Ashe, Cecil,

Table 2.—Persistence of DDT in soils of different regions.

REGION	NUMBER OF SOILS	POUNDS PER ACRE AFTER INDICATED MONTHS				
		0–4	12–16	24–28	36–40	48–52
Southern New England	30	25.0	24.3	22.0	18.7	14.4
New York	2	25.0	24.8	21.8	18.5	14.0
Northeastern Ohio	15	25.0	24.1	21.4	17.9	14.6
New Jersey	28	25.0	24.8	23.9	21.6	18.9
North Carolina	9	25.0	24.5	23.6	22.5	21.3

Table 3.—Persistence of DDT in soils of different texture.

Texture	Number of Soils	Pounds per Acre After Indicated Months						
		0–4	12–16	24–28	36–40	48–52	72–76	96–100
Sand	3	25.0	24.8	23.3	22.0	21.0	20.8	18.5
Shale and gravelly or stony loam	6	25.0	24.8	22.3	18.6	14.6	12.0	10.0
Sandy loam	37	25.0	24.6	22.9	20.4	16.8	14.9	12.9
Loam	21	25.0	24.0	21.9	18.7	14.8	13.5	9.4
Silt loam	12	25.0	24.9	23.9	21.1	16.7	11.7	8.5
Clay loam	5	25.0	23.4	21.4	18.7	—	—	—
Muck	1	23.0	14.0	9.5	6.0	3.5	—	—

Davidson, Durham, Georgeville, Helena, Iredell, and Marlboro.

The average residual DDT in the soils of these regions was determined at intervals after application, and the results are summarized in table 2.

After 4 years about 85 per cent of the DDT remained in the North Carolina soils. This level was found in the New Jersey soils after 3.1 years, in the Ohio soils after 2.0 years, and in the New York and New England soils after 2.2 years. These figures indicate that the persistence of DDT in soil tends to increase from north to south. According to pedologists (Joffe & Conybeare 1943), there is a tendency for organic matter to decrease from north to south. It seems, therefore, that the persistence of DDT in soil may have some relation to the organic matter.

Effect of Texture.—The soils of the different series were grouped according to texture to determine whether the texture had any significant effect on the persistence of DDT. The average residual DDT in soils of different texture at various intervals is summarized in table 3.

In the sands 74 per cent of the DDT remained after 8 years, but in the other textural groups there was much less DDT. The residual DDT was reduced to this level in the shale and gravelly or stony loams in 3.0 years; in the sandy loams in 3.5 years; in the loams in 3.1 years; in the silt loams in 3.6 years; in the clay loams in 3.1 years, and in the muck in 0.5 year. The DDT was thus the most persistent in the sands and the least persistent in muck; the persistence was of about the same order in the different types of loams.

Table 4.—Relation between organic matter and persistence of DDT in soil.

Number of Soils	Average Per Cent Organic Matter	Average Pounds of DDT per Acre After 3 Years
6	0.68	23.4
8	1.39	22.0
11	2.21	20.8
14	2.76	20.4
7	3.37	18.6
6	4.38	16.5
1	29.12	6.0

Effect of pH.—It was thought that the pH of the soil might affect the longevity of DDT. Although little information was obtained on the pH of soils used in this investigation, general data from certain of the soil types (Lipman *et al.* 1940; Joffe & Conybeare 1943) indicate that within the range 4.0 to 7.5 the pH of the soil had little effect on the longevity of the DDT.

Effect of Organic Matter.—From the low recovery of DDT in muck and the results of other experiments in which different amounts of peat were added to soil, it appeared that the organic matter might be an important factor in the longevity of the toxicant. Little information was available on the organic content of the soils used in this investigation, but the nitrogen content of 53 of them had been determined by various investigators (Lipman *et al.* 1940 Joffe & Conybeare 1943). The organic matter in these soils was calculated by multiplying the percentage of nitrogen present by the factor 17.24, a method used by pedologists (Joffe & Conybeare 1943). The soils were then grouped according to the percentage of their organic matter, and the average residual DDT after 3 years was determined for each group. These data, summarized in table 4, show that the more organic matter present the less persistent was the DDT.

Summary.—An investigation was begun in 1943 of the persistence of DDT in

representative soils of the region infested with the Japanese beetle, *Popillia japonica* Newm. A total of 84 mineral soils and 1 muck were obtained from Connecticut, Massachusetts, Rhode Island, New Jersey, New York, Ohio, Virginia, and North Carolina and treated with DDT at the rate of 25 pounds per acre. A few of these soils were treated at the rate of 50 pounds per acre. The residual DDT in these soils was determined at intervals by bioassay, using third-instar larvae of the Japanese beetle.

The average residual DDT in the soils treated at the rate of 25 pounds per acre was as follows: 1 year, 97 per cent; 2 years, 90 per cent; 3 years, 79 per cent; 4 years, 64 per cent; 6 years, 56 per cent; and 8 years, 44 per cent. With the 50-pound treatment the loss was much the same. When DDT was mixed with soil the loss was less than when it was applied as a top-dressing to turf. However, its persistence was modified by factors other than the method of application.

In two-thirds of the soils about half the DDT remained after 8 years, and in nine-tenths of them one-fourth or more was found after this period.

A tendency for the persistence of DDT to increase from north to south indicated that there might be some relation between its longevity and the organic content of the soil in a region.

DDT was most persistent in sand and least so in muck; in the different types of loam the persistence was much the same. The pH within the range of 4.0 to 7.5 seemed to have no effect. The more organic matter in the soil the less persistent was the DDT.

LITERATURE CITED

Cullinan, F. P. 1949. Some new insecticides—their effect on plants and soils. JOUR. ECON. ENT. **42:** 387–91.

Fleming, W. E. 1950. Persistence of effect of DDT on Japanese beetle larvae in New Jersey soils. JOUR. ECON. ENT. **43:** 87–9.

Fleming, W. E., L. W. Coles, and W. W. Maines. 1951. Biological assay of residues of DDT and chlordane in soil using *Macrocentrus ancylivorus* as a test insect. JOUR. ECON. ENT. **44:** 310–315.

Fleming, W. E., L. W. Coles, and W. W. Maines. 1951-a. Persistence of chlorinated hydrocarbon insecticides in turf treated to control the Japanese beetle. U. S. Bur. Ent. and Plant Quar. E-829, 6 pp.

Fleming, W. E., and I. M. Hawley. 1950. A large-scale test with DDT to control the Japanese beetle. JOUR. ECON. ENT. **43:** 586–90.

Fleming, W. E., and W. W. Maines. 1947. The effectiveness and duration of treatments with technical DDT in different soils against larvae of the Japanese beetle. U. S. Bur. Ent. and Plant Quar. E-**716,** 20 pp.

Foster, A. C. 1951. Some plant responses to certain insecticides in soil. U. S. Dept. Agr. Circ. 862.

Joffe, J. S., and Adrienne B. Conybeare. 1943. Analysis of United States soils. Section II: South Atlantic States. N. J. Agr. Expt. Sta. Spec. Pub.

Lipman, J. G., J. S. Joffe, and Adrienne B. Conybeare. 1940. Analysis of United States soils. Section I: North Atlantic States. N. J. Agr. Expt. Sta. Spec. Pub.

Polivka, J. B. 1947. DDT for controlling the larvae of Japanese beetle. Ohio Agr. Expt. Station Farm and Home Research. May-June.

Polivka, J. B. 1952. Field tests of insecticides for control of Japanese beetle larvae. JOUR. ECON. ENT. **45:** 251–4.

Schread, J. C. 1949. Residual activities of insecticides in control of turf insects. JOUR. ECON. ENT. **42:** 383–7.

Smith, M. S. 1948. Persistence of DDT and benzene hexachloride in soils. Ann. Appl. Biol. **34:** 494–504.

Life History and Control of Pecan Spittlebug

S. C. Chandler[1]

Severe infestation by a spittlebug on pecan in Illinois led to a study of the insect in 1951 and 1952. The progressive decrease in crop yields previous to the study was attributed partly to the effect of feeding of the nymphs on or just below the young nuts, but mostly to the killing of the terminal shoots of the branches which would have produced fruit buds the following year. Examinations made in February, 1952, showed 87 per cent of the terminals killed in the unsprayed block as compared with 3 to 5 per cent in the blocks receiving a lindane spray in July, 1951 (Fig. 1).

Fig. 1.—Terminal shoots of pecan: Left, unsprayed; right, sprayed.

Nomenclature.—The pecan spittlebug is generally referred to in the rather meager economic literature as *Clastoptera obtusa* Say, but it is the opinion of Dr. Kathleen Doering, a specialist in the group, that her determination, Doering (1942), is correct and the species working on pecan is *Clastoptera achatina* Germ. Correspondence with Dr. B. A. Porter, B.E.P.Q., after specimens from Illinois had been sent to the National Museum indicates that earlier determinations may have been in error and that *C. achatina* Germ. may well be the dominant if not the only species on pecan.

Life History.—Apparently the only published account of the life history was written by Leiby (1925), where the species is given as *Clastoptera obtusa* Say. He reports that in North Carolina eggs are deposited under the bark in the fall and sealed over with a wax-like substance. Nymphs appear on nut and leaf stalks shortly after nuts are set, in early May in Georgia, begin feeding, cover themselves with spittle, and remain in one place during their period of growth. They then abandon the spittle and transform to the adult stage. Adult bugs are 2.5 mm. in length, pale brown with a reddish tinge, with darker areas of brown on the middle of the forewings. Adults are found the latter part of June or early July, and produce a second brood of nymphs in August.

In Illinois life history studies were begun in 1951 at Anna in extreme southern Illinois, beginning with the appearance of the first nymphs of the season in early June. In chronological order the following events in the development of the insect were observed at Anna:

June 12 First brood nymphs still feeding but decreasing in numbers and spittle drying.

June 27 Nearly all nymphs and spittle gone, adults appearing.

July 8 First appearance of second brood nymphs.

July 16 Large numbers of second brood nymphs and spittle masses in evidence.

Aug. 3 Nymphs and spittle decreasing, adults increasing.

Aug. 31 Spittle and nymphs mostly gone.

Emergence of adults in screen cages placed over infested branches July 23:
Aug. 3, 6 adults; Aug. 6, 12; Aug. 8, 3; Aug. 10, 15; Aug. 13, 14; Aug. 15, 5; Aug. 18, 4; Aug. 21, 3; Aug. 24, 4; Aug. 26, 1; Aug. 31, 1.

Aug. 15 and 24 Adults placed in cages over terminals of pecan laid eggs in wood and died. There was no evidence of a third generation.

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FIG. 2.—Pecan spittlebug eggs in pecan twig.

Hibernating eggs were examined in the fall of 1951 and spring of 1952. As many as five or six eggs were deposited in slits (Fig. 2) which were approximately 3 mm. in length, and embedded deep enough in the wood that they could seldom be seen without opening the slits. The majority of the egg slits were found in pairs, separated by a space about the length of the slit. Many slits were found to contain only empty egg shells, presumably from the preceding brood, but possibly from earlier broods, as the slits were quite generally corked over, protecting them from weathering. In March, 1952, branches from the pecan orchard, heavily infested in 1951, were examined to determine the abundance and relative occurrence of eggs and egg shells in sprayed and unsprayed blocks. Results of these examinations are shown in table 1.

From table 1 it appears that in unsprayed trees the ratio of egg slits containing eggs to those with egg shells is about 1 to 6, but in blocks where good control was obtained, few or no live eggs were found; that eggs are not laid in the current season's growth, as most of the 0.12 to 0.25 inch wood was 1951 growth, nor in wood over 0.5 inch in diameter; that the choice of wood diameter for oviposition was 0.25 inch, if we assume that egg shells are from the preceding season's brood and that $\frac{3}{8}$ inch wood was $\frac{1}{4}$ inch at time of egg laying.

In 1952 observations on life history of the spittlebug were made both at Anna and at Eldred, 180 miles northwest. Due to unusual weather conditions in 1952 there was not the normal difference in time in the development of the various stages of the insect or the host that this distance should produce. The first appearance of nymphs at Anna was followed only four days later by the same event at Eldred. The sequence of events in spittlebug and pecan development are shown in table 2.

Table 1.—Location and numbers of egg slits containing live eggs and egg shells of spittlebug in branches of varying sizes, located in 1951 spray plots. Examinations made March 1952.

Treatments 1951	Per Cent Kill of Nymphs, 1951	Inches of Branch Examined	Diameter of Branch, Inches					Slits Containing	Totals
			0.125 to 1.4	1.4	3.8	1.2	0.5 to 1		
Lindane	96–100	1094	0	0	0	0	0	Live Eggs	0
			0	10	47	19	0	Egg Shells	76
Totals, Eggs and Egg Shells			0	10	47	19	0		76
Percentages			0.0	13.15	61.84	25.0	0.0		
Unsprayed	0	508	2	4	3	1	0	Live Eggs	10
			0	15	44	4	0	Egg Shells	63
Totals, Eggs and Egg Shells			2	19	47	5	0		73
Percentages			2.74	26.02	64.38	6.85	0.0		

Note: The number of egg shells found in the 0.375 inch size is highly significant, but the numbers of live eggs are too small to ascertain significance.

Table 2.—Pecan spittlebug and nut development, Anna, 1952.

INSECT	DATE	TREE
Dormant eggs in branch	Apr. 24	Catkins 0.5 to 0.75 inch
First nymphs on wood	May 5	Catkins 1 to 1.5 inches
Many nymphs and spittle masses	May 12	Catkins 2 to 3 inches
Peak hatch first brood	May 20	Female flowers in evidence
Spittle drying, first adults seen	June 2	Small nuts showing
Peak occurrence of adults	June 7–10	
Adults decreasing in numbers	June 14	
Adults nearly all gone	June 20	
First second brood nymphs	June 27	
Hatch mostly over, peak numbers nymphs	July 7	
Spittle drying, adults appearing	July 26	
Spittle nearly all gone	Aug. 5	

Of practical importance to growers is the increase of second brood over first. Using branch terminals with several growing points as a unit, infestation records in unsprayed blocks were made at peaks of first and second broods. The results are shown in table 3.

It was thought that a flash flood of over 3 inches at Anna on June 9 may have affected the natural rate of increase. The infestation even at Eldred was decidedly lower than in 1951.

CONTROL.—Preliminary tests in 1951, reported by Chandler (1952), gave the following degree of control with one application of insecticide: lindane, 1 lb. 25 per cent wettable powder per 100 gallons, 96 to 100 per cent; parathion, 1.5 lbs. 15 per cent wettable powder per 100 gallons, 62 to 64 per cent; TEPP, 0.33 pint, 40 per cent.

Spraying experiments were conducted in 1952 at Eldred in the first and second broods and at Anna in the second brood period.

SPRAYING TESTS AT ELDRED.—Spraying operations at Eldred were handicapped by the fact that the "mechanical aerosol generator," used with its small output of liquid, was not very well fitted for orchard work, and by the fact that the trees were grafted in their original positions in the woods, making access to them difficult. Some could be reached from one side only. As an exploratory dosage, the two materials available at the time were used at about six times the usual amounts per 100 gallons, dieldrin at 1 gallon of 18.5 per cent, and lindane at 1 gallon of 20 per cent gamma isomer. First examination 6 days after spraying showed 91 spittle masses with live nymphs per 100 in the unsprayed as against 18 in the dieldrin and 35 in the lindane blocks.

Table 3.—Infestation of first and second broods, 1952, and number of spittle masses per 100 terminals at peak periods.

LOCATION	FIRST BROOD	SECOND BROOD	INCREASE	PER CENT INCREASE
Anna	41	62	21	51.2
Eldred	23	50	27	117.4

Table 4.—Numbers of spittle masses in 400 terminals of pecan 17 days after spraying.

TREATMENT	NO. MASSES	PER CENT CONTROL
Dieldrin	18	90.5
Lindane	27	85.7
Check	189	0.0

Note: Dieldrin is significantly better than lindane and both are highly significant as compared with check.

Since it was found that approximately the same number of terminals examined at random were required to find 100 spittle masses in each block, records in the second examination, 17 days after spraying, were made of total masses of spittle in 400 terminals. These are given in table 4.

For second brood sprays at Eldred, the dosages given above were increased by one-half. To improve coverage under the difficult conditions, ten medium-sized trees more accessible than the average, were selected in each block and marked prior to spraying. They were given a more thorough spraying than the average of the plots and all records were made of these ten trees. Population records were made the day before spraying, 3 days after spraying, and 10 days after spraying. For population records, 20 terminals of branches were examined around each

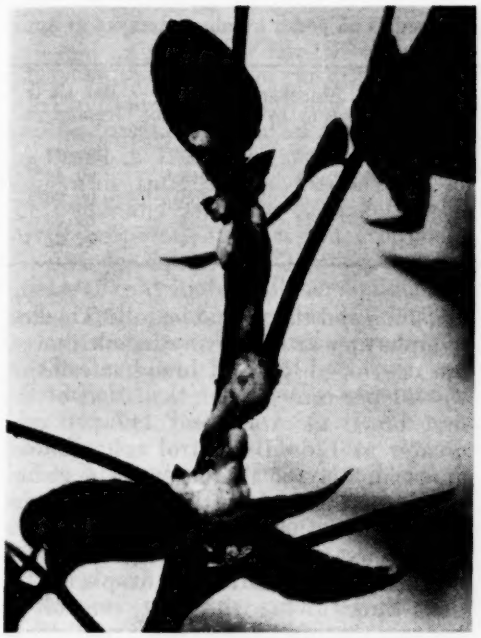

FIG. 3.—Spittle of pecan spittlebug on terminal and nut.

FIG. 4.—Nymphs of pecan spittlebug, July 1951.

tree, about as many as could be pulled down with a hooked pole. This made a total of 200 terminals per plot. Since the sprays had been delayed until maximum numbers of nymphs were present, by the time of the 10-day examination, there was a natural decrease, so reduction was computed from the records made 3 days after spraying and are shown in table 5.

SECOND BROOD SPRAYS, ANNA, 1952.—At Anna a conventional sprayer was used, with 600 lbs. pressure, using a single gun from the top of the spray rig. Trees were 32 years old, 50 to 75 feet high, and growing in regular orchard rows 55 feet apart. They required 25 gallons per tree to spray to the point of runoff.

Records were made in a similar manner to those in the second brood sprays at Eldred with reduction based on records taken just before and three days after spraying. These data are summarized in table 6. In these tests every block was separated from the others by a block of peaches or apples except the small check block which was adjacent to the toxaphene block. It is quite possible that the reduction shown in table 6 was due to this fact.

VARIETAL SUSCEPTIBILITY.—Infestation records were kept of each tree separately, and variety recorded. At Anna and Eldred the most common varieties in the plots were Butterick, Busseron, Green River, Indiana, and Posey. At Eldred two other common varieties were Kentucky and Duis. Of these, Indiana had a somewhat higher infestation than the others, with Posey showing some evi-

Table 5.—Number of spittle masses containing live nymphs on 200 terminals of pecan, at Eldred, sprayed July 18, 1952.

TREATMENTS	AMOUNTS PER 100 GALLONS	MASSES JULY 17	MASSES JULY 21	REDUCTION	PER CENT REDUCTION
1. Dieldrin	1.5 gal. of 18½%	130	19	114	85.38
2. Lindane	1.5 gal. of 20% gamma	123	24	99	80.48
3. BHC	2.5 gal. of 11.7%	98	11	87	87.77
4. Toxaphene	2 gal. of 58.5%	107	16	91	85.0
5. Check	—	99	98	1	1.0

Note: The treatments are highly significant over the check but there is no significant differences between them.

Table 6.—Number of spittle masses containing live nymphs on pecan terminals sprayed at Anna, July 11, 1952.

TREATMENTS	AMOUNTS PER 100 GALLONS	MASSES JULY 10–11	MASSES JULY 14	REDUCTION	PER CENT REDUCTION
1. Dieldrin	1.33 pints of 18½%	148	3	145	97.97
2. Lindane	1 lb. of 25% wet. powder	214	1	213	99.53
3. BHC	2.5 lbs. of 10% wet. powder	258	5	253	98.06
4. Toxaphene	1 qt. of 31%	146	22	124	84.93
5. Check (next to toxaphene)		61	47	14	22.95

dence also of being more susceptible. At Eldred, Kentucky showed a fairly consistent high infestation.

SUMMARY.—The pecan spittlebug, determined as *Clastoptera achatina* Germ., is probably the same as has been referred to as *C. obtusa* Say. Greatest injury appears to be reduction of crop due to killing of terminal shoots which would would have produced bud-bearing wood. The insect hibernates in the egg stage, inserted into slits in wood chiefly of 0.25 to 0.375 inches in diameter. Two broods of nymphs develop on pecan in southern Illinois, the first chiefly in May and June and the second in July. The first nymphs appear before any female flowers are developed. Second brood infestation was 51 per cent greater than that of the first brood at Anna and 117 per cent greater at Eldred. Control tests showed approximately 85 to 100 per cent reduction in numbers of spittle masses containing live nymphs with one spray application in first or second brood periods with dieldrin, lindane, BHC, or toxaphene, the first three giving the best control. It appears that we have a choice of dieldrin, lindane, and BHC, with BHC practically as efficient as the more expensive lindane.

LITERATURE CITED

Chandler, S. C. 1952. Life History and Control of Pecan Spittlebug in Illinois, JOUR. ECON. ENT. **45**(5): 890.

Doering, Kathleen, Jour. Kan. Soc. **15**(3): 65–92. 1942.

Leiby, R. W. Insect Enemies of the Pecan in North Carolina. Bull. Dept. Agr., 44–5. February 1925.

Torsalo and Tick Control with Toxaphene in Central America[1]

ERNEST W. LAAKE[2]

The torsalo, *Dermatobia hominis* L., and the fever tick, *Boophilus annulatus var. microplus*, are the most common and important external parasites of cattle in Central America. They are responsible for serious injury and tremendous losses to the cattle industry. Government officials of the various countries and, especially, the larger and more progressive owners of beef and dairy cattle have long recognized the need for efficient and practical control of these insects in order to increase production of beef, milk, leather, and other beef and dairy products, all of which are so vital to the health and living standards of these rapidly growing nations.

Although cattle baths containing arsenious oxide as the active agent have been used extensively for years in tick control in Central and South America, it was not until April 5, 1948, that the author introduced into Brazil toxaphene,[3] an insecticide that later proved to be an efficient and practical means of controlling torsalo. Brazilian cattle on the fazenda of the Inspetoria Regional de Pinheiral, a Federal Experiment Station in the state of

[1] This work was carried out as part of the Point IV program, administered by the Technical Cooperation Administration, U. S. Department of State, through the Institute of Inter-American Affairs.

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[3] Laake, E. W. Livestock Parasite Control Investigations and Demonstrations. Part 2. JOUR. ECON. ENT. 42:(2) 276–80. April 1949.

Rio de Janeiro, were the first torsalo-infested animals ever treated with toxaphene and with some of the other chlorinated hydrocarbon insecticides.[4]

The torsalo-tick-control investigations in Brazil in 1948 were sponsored by the American International Association for Economic and Social Development, a nonprofit corporation, of which Nelson A. Rockefeller is president. The corporation's goal is to contribute to higher standards of living and opportunities for self-development among people of various countries.

The excellent control of tick and torsalo that was eventually obtained in the Brazilian tests with toxaphene were soon further explored in other torsalo-infested countries. These investigations confirmed the efficacy of toxaphene as an outstanding insecticide, both for the fever tick and for the insects that carry and deposit the torsalo eggs and grubs.

TOXICITY OF TOXAPHENE TO CATTLE.—Since 1948 the Bureau of Entomology and Plant Quarantine and the Bureau of Animal Industry of the United States Department of Agriculture, working in cooperation with the insecticide industry and some of the State experiment stations in the United States, have determined the toxicity of all well-known chlorinated hydrocarbon insecticides to domestic animals, especially to cattle, sheep, and goats. Their principal investigations were designed to determine (1) the minimum lethal dose of each of these materials, both when applied externally as sprays, dips, etc., and when administered orally with treated feed, for animals of various breeds or species and of various ages, (2) the amount of each insecticide absorbed by the tissues of the animals after single or repeated treatments in concentrations required for practical control of livestock insects, or after feedings of silage, hay, or other feedstuff that had been treated for insect control, and (3) the period that the insecticide remained in the tissues and in milk after single or repeated treatments or feedings. These investigations included tests in which toxaphene was both applied in 0.5-per cent concentration (to cattle) twice a month for 6 months and administered orally (to cattle and sheep) with feed in

[4] Laake, E. W. Livestock Parasite Control Investigations and Demonstrations in Brazil. Part 1. Paper read in Dept. of Agriculture, Rio de Janeiro, Brazil. May 14, 1948. Mimeographed.

FIG. 1.—Eggs of *Dermatobia hominis* (L.) on female *Musca domestica* L.

a concentration of 100 mg./kg. for months at a time, all without any sign of ill effect. Because there is no specific test for toxaphene, the amount of this insecticide present in milk following treatment or ingestion cannot be determined. However, on the basis of organically bound chlorine which has been carefully determined by chemical analysis in hundreds of samples of milk from treated cows, it is indicated that the amount of toxaphene excreted in milk, if any, is so small that there is little danger of contaminating milk or making it unfit for human consumption.

TOXAPHENE FORMULATIONS FOR THE CONTROL OF LIVESTOCK INSECTS.—Wettable powders and emulsifiable concentrates are both suitable for livestock treatments. The old, coarse, wettable powders, which suspended so poorly and were not suitable for use in hand sprayers or in dipping vats, have recently been replaced by new formulations of so-called supersuspensible wettable powders that are excellent for use in any type of hand or power sprayer and in dipping vats. These new wettable powders, containing 40 per cent toxaphene, are highly efficient in controlling the fever tick and the torsalo-egg-carrying insects and, when properly used, are nontoxic to cattle and all other domestic animals, except possibly dogs. Besides, they are considerably cheaper than any other chlorinated hydrocarbon insecticide that can be used safely for repeated treatment—a great advantage, for the treatment must be often repeated if good control is to be accomplished. These fine new powders will be preferred to any other formulation for livestock treatment and eventually will be used more extensively.

Tremendous progress also has been made during the last year with the development of toxaphene emulsions that are stable in dipping vats in all types of water in which they have been tested in the United States and in Central America. This development will protect animals from the large overdoses of toxaphene that have occurred all too frequently in vats filled with unstable emulsions and have resulted in the loss of many animals. Most of the toxaphene emulsifiable concentrates made until early in 1952 were suitable for spraying when they were properly diluted to safe concentrations, but none were stable or safe for use in dipping vats. Manufacturers who dump unstable concentrates on foreign markets that have no restrictions obviously will not assume responsibility for losses resulting from the use of their product. It is important, therefore, not to purchase toxaphene emulsifiable concentrates for use in dipping vats unless they are known to have been extensively field-tested and found to be stable in all types of water. At least a few of the new stable concentrates have become available in Central and South American markets.

TORSALO AND TICK CONTROL IN NICARAGUA AND COSTA RICA.—*Nicaragua.*—In 1950 Enrique Sanchez, Minister of Agriculture of Nicaragua, working in cooperation with the Servicio Técnico Agrícola de Nicaragua under the direction of Virgil Peterson and his staff, inaugurated a torsalo-tick-control program extending over approximately 400 square miles near Matagalpa, Nicaragua. The area contained about 10,000 cattle all heavily infested with torsalo and fever ticks. Because the terrain over most of the control area was so rough that the driving of motorized vehicles was practically impossible, especially during the rainy season, it was necessary to conduct all control operations by horseback and pack mules.

A 0.5-per cent toxaphene emulsion made from emulsifiable concentrates was used for all spraying and also for charging a single dipping vat. Simple chutes made from bamboo cane or saplings, at little or no cost other than that of labor, were built by all farmers in the control areas for retaining the cattle while they were being sprayed. Though simple and inexpensive, these facilities are highly essential for rapid and efficient spraying of animals.

The project was started with a crew of two spray operators and one supervisor-organizer. As soon as the first crew got established, two more crews were added. Together, the three two-man crews and one supervisor were able to spray all the cattle in the control area at fairly regular intervals twice each month. During the first months of the program all spraying was done with standard knapsack sprayers, but because the day-long operation of these sprayers became too tiresome and burdensome for the operators to do good work, they were discarded and replaced

by hand-operated barrel pumps, without the barrels. The pumps were mounted on tubs or, more often, on 50-gallon oil drums instead of on barrels; and these improvisations were furnished by each cattle owner.

The torsalo incidence in the control area before toxaphene treatment began was very heavy, perhaps heavier than in any other part of Nicaragua. On one farm 253,939 torsalo grubs, by actual count, were extracted from 300 cows and calves during April-December 1950, or an average of 846 grubs per animal during the 9-month period. In contrast, during the first 9 months after spraying began in 1951, only 12,804 grubs were removed from 210 adult cattle and 97 calves in the same herd, or an average of 41.7 grubs per animal. Besides, more than 82 per cent of these were removed during the first 3 months. At the time this herd was inspected by the author, approximately 9 months after spraying had been started, it harbored less than one torsalo grub per animal. The fever tick also had disappeared from the herd.

The results of this program demonstrate that (1) torsalo can be effectively controlled with 0.5 per cent toxaphene spray applied at regular intervals, (2) simple and inexpensive hand-operated spray pumps can serve satisfactorily for spraying cattle scattered over a 400-square-mile area that, with the exception of one dipping vat, has no other facilities for treating cattle, and (3) a control program is possible and even practical in an area where the terrain is so rough that all travel and transportation must be done by horseback and pack mule.

In Nicaragua the Ministry of Agriculture has extended the torsalo-tick-control program to other areas in the country.

Costa Rica.—Early in January 1952 Claudio A. Volio, Minister of Agriculture in Costa Rica, assisted by Francisco Seravalli and his staff, Departamento Agropecuario, and the author started an extensive torsalo-tick-control program in San Carlos Canton in central-eastern Costa Rica, in Provincia de Alajuela. This canton, divided into five districts, contains at least 30,000 cattle. Because of the good year-round grazing in San Carlos Canton, beef cattle from other areas, particularly from the Guanacaste Province, are brought there for fattening and slaughter. Milk cattle also are found in considerable numbers in all San Carlos districts.

Torsalo and fever ticks are very abundant and do much damage in cattle herd throughout San Carlos Canton. Work oxen harbor more torsalo than any other class or group of cattle. Individuals in this group, particularly in the Florencia District have been estimated to harbor as many as 600 torsalo larvae. Cattle of all breeds, including Zebu, and of all ages, are infested with both torsalo and ticks. Lice, principally a species of tail louse, *Haematopinus quadripertusus* Fah., are found on most of the cattle brought into San Carlos from the Guanacaste. The stable fly, *Stomoxys calcitrans*, the horn fly, *Siphona irritans*, and particularly the house fly, *Musca domestica*, all potent carriers of torsalo eggs, are found in at least moderate abundance in all San Carlos. Mosquitoes of various species also undoubtedly contribute toward the heavy torsalo infestation of cattle and of some wild animals in this area.

Personnel of the insect-control program in San Carlos consists of nine men: three field crews of two men each; a jeep driver, who commutes between the crews and supplies them with their various needs; an office attendant; and an area supervisor. Each crew is provided with a small power sprayer and a number of knapsack sprayers, together with such accessories as are needed for their work. All crews are motorized, but once the rainy season gets well under way they have to travel by horseback and pack mule.

Toxaphene is the only insecticide used in San Carlos Canton for the control of ticks, lice, and torsalo-egg-carrying insects. Emulsifiable concentrates containing 50 to 65 per cent toxaphene are being used for spraying; these are the old formulations. A few dipping vats in the area have been charged with the new, stable emulsions of toxaphene, with a concentration of 0.37 per cent technical toxaphene. For spraying, the new emulsions are used in a concentration of 0.5 per cent.

Although the torsalo-tick-control program in San Carlos has merely begun, ticks have disappeared from animals that formerly were heavily infested, and torsalo infestation has already been reduced considerably wherever animals have been sprayed or dipped at least three times. Beef cattle are improving in condition,

and dairy farmers claim that their milk, butter, and cheese production has been greatly increased. Without exception, cattle owners in the control area are greatly pleased with the good results.

Other torsalo-tick-control programs using toxaphene are under way on individual ranches in Costa Rica and are producing splendid results. The systematic spraying of some 2,000 cattle on the United Fruit Company's Hacienda Tenorio, in Guanacaste Province, for 5 months, or in approximately 10 treatments, has eliminated both torsalo and ticks to the point where the managers of the Hacienda feel that only occasional treatments will be needed to control both of these serious livestock pests.

Dermatobia hominis is found only in Central and South America. In all areas where it has become well established it is the worst insect enemy of cattle in the world. It has a wide variety of hosts, including man. It is commonly found in dogs. Only recently a parasitologist at the Texas Agricultural and Mechanical College found live, encysted *D. hominis* larvae in a dog that had been brought into Texas from Central America. Apparently the infestation was not observed by port-quarantine inspectors. Because of the serious consequences that would result once this dangerous insect became established in the United States, every precaution should be taken by our state and federal quarantine organizations to prevent its introduction into the United States.

Food Habits of Coniopterygids on Citrus in Southern California[1]

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Coniopterygids, or dusty wings as they are commonly called, are among the most effective natural enemies of the citrus red mite, *Metatetranychus citri* (McG.), in southern California (De Bach *et al.* 1950). Four species representing four genera of the family Coniopterygidae are found in California citrus groves. They are *Parasemidalis flaviceps* Banks, *Conwentzia nigrans* Carpenter, *Coniopteryx* (undescribed), and *Malacomyza* sp., named in order of their decreasing abundance in citrus groves. The first three species are of common occurrence, but the fourth is found only occasionally.

In the past, dusty wings on citrus in California have been considered to be primary predators of mites (Quayle 1938, Ebeling 1950, De Bach *et al.* 1950). Repeated attempts to raise dusty wings on citrus red mites, alone, in the insectary were unsuccessful, however. The food habits of these dusty wings have therefore been studied in the laboratory.

EXPERIMENTAL PROCEDURE.—All experiments were carried on in a room of the insectary of the Department of Biological Control of the University of California Citrus Experiment Station at Riverside. A temperature of about 80° F. and a relative humidity of about 50 per cent were maintained throughout the course of the experiments. Totals of 1,500 adults and 250 larvae, representing the genera *Parasemidalis*, *Conwentzia*, and *Coniopteryx*, were tested.

The field-collected dusty wing adults used in these studies were subjected to the conditions of the experiments the day of collection or the following day. Life span and egg production were determined for adults restricted to any one of the seven following diets: (1) citrus red mites plus water; (2) citrus red mites plus honey; (3) crawlers of the California red scale, *Aonidiella citrina* (Coq.); (4) crawlers of California red scale plus honey; (5) honey; (6) honeydew from the black scale, *Saissetia oleae* (Bern.); or (7) nectar from extrafloral nectaries of the castor bean plant, *Ricinus communis* L.

The food substances to be tested were generally placed on the upper surface of clean citrus leaves, which, in turn, were placed in test tubes. Ten adults (sex ratio undetermined) were put into each tube,

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and the tubes were then closed with a cotton plug. The leaf and the food supply were renewed every other day. Care was taken to insure a superabundance of food at all times.

Dusty wing larvae used in these experiments were obtained from eggs produced in the insectary by field-collected adults. Attempts were made to rear larvae when restricted to any one of three different diets: (1) mixed ages of citrus red mites; (2) mixed ages of California red scale, or (3) eggs of the potato tuberworm moth, *Gnorimoschema operculella* (Zell.). The larvae were confined with the food material to be tested in a wide-mouthed pint mason jar covered with bolting cloth. Since the larvae are cannibalistic, only one was used for each test unit.

The citrus red mites used as food for the adult dusty wings were obtained from heavily infested field-collected citrus leaves. The red scale crawlers were from insectary-reared adults. The black scale honeydew was collected by placing sheets of waxed paper under colonies of black scale feeding on cow melons (*Citrullus vulgaris*) in the insectary. The plant nectar was collected daily from the large extrafloral nectaries at the base of the leaves on castor bean plants.

The citrus red mites used as food for the dusty wing larvae originated from field-collected stock placed on citrus fruits in the insectary. The fruit was infested about one week before it was to be used, so that supplies of eggs and other immature stages were present to serve as food for the newly hatched dusty wing larvae. The California red scale used as food for the larvae was insectary-reared on Irish potatoes or citrus fruits. All stages from crawlers to adults were present on each fruit or potato used in these experiments. The eggs of the potato tuberworm moth deposited on sheets of waxed paper by insectary-reared moths were supplied by Glenn Finney of the Albany insectary of the University of California Department of Biological Control.

NUTRITIONAL TESTS WITH DUSTY WING ADULTS.—In these experiments 1,500 adults were used, but for several reasons this must be considered only a preliminary investigation. Since the adults were collected in the field, their age and nutritional history were unknown. Further, since the sex ratio was unknown, the number of females present in any experimental group was indefinite. In addition it should be mentioned that the adults were collected from various citrus-producing areas in southern California and that the experiments were in progress from June until December of 1950. In spite of these irregularities, a considerable amount of progress has been made towards gaining an understanding of the general food requirements of these important predators.

Egg production and longevity records obtained for each species from six different diets are shown in table 1. Figures for egg production represent the total number of eggs produced by all 10 individuals of any one test group. Longevity records show the maximum life span, in days, attained by any one individual of the test group. From the data presented in table 1, it is evident the when adults of *Parasemidalis flaviceps* were restricted to a diet of mites or red scale they were short-lived and egg production was poor, and that when they were restricted to a diet of honey or black scale honeydew both egg production and life span increased considerably. Maxi-

Table 1.—Effect of diet on egg production and longevity of test groups of 10 adults each (sex ratio unknown) of three species of dusty wings *Parasemidalis flaviceps*, *Conwentzia nigrans*, and *Coniopteryx* sp.).

	P. flaviceps		*C. nigrans*		*Coniopteryx* sp.	
DIET	Number of Eggs	Maximum Life (Days)	Number of Eggs	Maximum Life (Days)	Number of Eggs	Maximum Life (Days)
Citrus red mites	7	4	6	6	3	3
California red scales	9	4	8	4	—[1]	—[1]
Honey	66	26	22	19	48	76
Honeydew	21	32	13	17	18	36
Mites and honey	134	39	144	36	198	122
Scales and honey	148	39	126	39	67	69

[1] Dash indicates no test.

mum egg production and longevity were obtained when diets included both honey and mites or honey and scale. In general, adults of *Conwentzia* and *Coniopteryx* responded in the same manner to the various diets as did adults of *Parasemidalis*.

It should be emphasized at this point that as the dusty wings used for these tests were field-collected, they had been provided with varying amounts of nutrients of unknown quality before the experiments were started. This nutrient material indubitably had some influence on the rate of oviposition for at least the first few days of the experiments. When the data are examined with this thought in mind, it may be seen that the effects of the various diets are even more striking than indicated in table 1. For example, when records for the first 3 days of the experiments were omitted, the general pattern of longevity and egg production for all species tested was similar to that shown for *Parasemidalis* in table 2.

To summarize briefly: Adult dusty wings of the species tested failed to survive on a diet of mites or scale alone. They survived on a diet of honey, alone, but produced few eggs on such a diet. When mites or scales were added to the honey diet, the life span tended to increase somewhat and there was a marked increase in the egg production.

In addition to the diets mentioned above, the adults of the three species of dusty wings were given diets of nectar, alone, from the extrafloral nectaries of the castor bean plant. The length of life and egg production of the dusty wings restricted to this food were about the same as those of the dusty wings fed on honey (Table 2).

Other natural sugar foods that were observed to be readily accepted by adult dusty wings were nectar from orange and avocado blossoms and honeydew from various aphids and from the mealybugs *Planococcus citri* (Risso) and *Pseudococcus adonidum* (L.).

NUTRITIONAL TESTS WITH DUSTY WING LARVAE.—Attempts were made to raise the larvae of *Parasemidalis*, *Conwentzia*, and *Coniopteryz* on diets of citrus red mites, California red scale, and eggs of the potato tuberworm moth.

Although 122 larvae were restricted to a diet of citrus red mites, not one of them developed to the adult stage. The majority of these larvae died in the second or third instar, but three of them reached the prepupal stage. One of these three entered the prepupal stage fully exposed on the surface of an orange, without spinning a cocoon; the other two spun cocoons; all three died in the prepupal stage.

Larvae of all three genera, *Parasemidalis*, *Conwentzia*, and *Coniopteryx*, readily developed to the adult stage on a diet consisting only of red scales. They fed readily on crawler, white cap, and molt stages of the red scale.

Eggs of the potato tuberworm moth were found to be a satisfactory food for dusty wing larvae. These eggs were used because large quantities of them were available at the Albany insectary, as explained above, and because a search was being made for suitable foods to be used in the insectary production of dusty wings. The fact that dusty wing larvae developed readily on these eggs indicates that a rather wide range of nutrient materials may be utilized by dusty wing larvae in their natural environment.

In the field, dusty wing larvae have been observed to feed on the eggs and small larvae of various species of insects;

Table 2.—Effect of diet on daily egg production of *Parasemidalis flaviceps* Banks, and on the number of live adults at the end of each day of the last 17 days of a 20-day period.[1]

DAY	DIET[2]					
	Honey		Honey and Citrus Red Mites		Honey and Red Scale Crawlers	
	Eggs	Live Adults	Eggs	Live Adults	Eggs	Live Adults
Fourth	5	9	12	9	7	10
Fifth	4	9	9	9	6	10
Sixth	5	9	7	9	8	10
Seventh	5	9	6	9	12	10
Eighth	1	9	5	9	7	10
Ninth	1	9	5	9	9	10
Tenth	2	9	7	8	6	10
Eleventh	1	7	9	7	4	10
Twelfth	0	7	8	7	4	9
Thirteenth	0	7	5	7	3	8
Fourteenth	0	5	7	7	3	7
Fifteenth	0	4	4	7	2	7
Sixteenth	0	4	12	5	6	5
Seventeenth	0	4	3	4	2	5
Eighteenth	0	4	5	4	1	5
Nineteenth	0	3	3	4	0	4
Twentieth	0	3	2	4	4	4
Total number of eggs laid after third day	24		109		84	

[1] Each test group consisted of 10 adult insects (sex ratio unknown).

[2] In test groups fed on citrus red mites alone, all adults were dead at the end of the fourth day, and no eggs were laid after the third day.

on many species of plant-feeding mites including some eriophyid mites; on all immature stages of black, soft (brown), and citricola scales; on crawler, white cap, and molt stages of various armored scales; and on honewdew and plant nectar.

FIELD OBSERVATIONS ON DUSTY WING POPULATIONS.—Although dusty wings on citrus in California have previously been considered primarily as predators of mites, information presented in this paper indicates that this is not necessarily true. Field data collected during the past few years show that dusty wings are general feeders. For example, population densities of dusty wings in citrus groves are not necessarily correlated with population densities of the citrus red mites. In fact, relatively high populations of dusty wings are frequently observed in groves where red mite populations are very low. In such groves unarmored or armored scales, plus some honeydew-secreting insects, are usually present. On the other hand, dusty wings may be scarce in groves which have high populations of mites but essentially no honeydew-secreting insects.

SIGNIFICANCE OF DUSTY WING FOOD HABITS IN THE BIOLOGICAL CONTROL OF MITES ON CITRUS.—Unpublished data obtained from cooperative field experiments with L. R. Jeppson of the Department of Entomology of this station have helped to demonstrate the significance of the food habits of dusty wings in the biological control of citrus red mites. In these experiments non-insecticidal spray and dust materials were used for mite control in citrus groves in an area where dusty wings were the principal mite predators present. Since the materials used were nontoxic to insects, the low populations of armored scale and honeydew-secreting insects in these groves were not disturbed. Thus, although the mites were eliminated, there remained a supply of insects and honeydew to furnish nutrients for the dusty wings remaining in the grove. This dusty wing population was instrumental in deterring a subsequent injurious mite infestation in these plots. In neighboring plots, however, which had been treated with acaricides that eliminated the insects as well as the mites, the dusty wings failed to become established even though the mite infestations became so serious as to require a second treatment for their control.

Population studies of citrus mites and their natural enemies in citrus groves in California during the past few years have shown that dusty wings are most effective as natural enemies of citrus mites in untreated groves in which all pests are under satisfactory biological control. Such varied prey populations furnish the complete diet required for dusty wings and thus render them efficient mite predators.

SUMMARY.—Adults of the dusty wings *Parasemidalis flaviceps* Banks, *Conwentzia nigrans* Carpenter, and *Coniopteryx* (undescribed) were fed any one of seven restricted diets: (1) citrus red mites, *Metatetranychus citri* (McG.); (2) citrus red mites plus honey; (3) crawlers of the California red scale, *Aonidiella citrina* (Coq.); (4) crawlers of the California red scale plus honey; (5) honey; (6) honeydew from the black scale, *Saissetia oleae* (Bern.); and (7) nectar from extrafloral nectaries of the castor bean plant, *Ricinus communis* L. They did not survive on a diet of mites or scales alone. On a diet of honey, alone, they survived but produced few eggs. When mites or scales were added to the honey, the life span increased slightly and egg production increased markedly.

Larvae of these dusty wings failed to develop on a diet consisting of citrus red mites only. They developed readily on diets of California red scale and tuberworm moth eggs.

In field experimental citrus plots, dusty wings and their host mites and insects were eliminated by the use of insecticidal acaricides. The dusty wings remained as effective predators, however, in plots where non-insecticidal acaricides were used.

LITERATURE CITED

DeBach, Paul, C. A. Fleschner, and E. J. Dietrick. 1950. Studies of the efficacy of natural enemies of citrus red mite in southern California. JOUR. ECON. ENT. **43**(6): 807–19.

Ebeling, Walter. 1950. Subtropical entomology. ix+747 p. Lithotype Process Company, San Francisco, California.

Quayle, H. J. 1938. Insects of citrus and other subtropical fruits. Comstock Publishing Co., Inc., Ithaca, New York.

Insecticidal Control Plot Tests for Pea Aphids in Relation to Alfalfa Hay Yields[1]

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A serious infestation of pea aphid, *Macrosiphum pisi* Kltb., developed in Kansas alfalfa fields during 1952. The most serious infestation developed as the alfalfa was emerging from winter dormancy. The first cutting of alfalfa frequently yields the majority of the hay produced in that year. This may be the only cutting when alfalfa is grown on upland. Serious loss may occur when pea aphids, cutworms, or other insects attack the first cutting.

The high rainfall of 1951 produced an abundance of subsoil moisture available to the alfalfa plant for use in the spring of 1952. This allowed the plants to grow vigorously when temperatures were sufficiently high. Temperatures, while such that the pea aphid could reproduce readily, were too low to permit the development of the lady beetles (chiefly *Hippodamia convergens* Guer.) which is their chief natural enemy in Kansas. These conditions allowed the pea aphid to damage the new growth of alfalfa to the point that the plants appeared to be wilting.

Materials and Equipment.—The following insecticides were applied to alfalfa in a Buffalo alfalfa field on the Fort Hays Experiment Station: aldrin, chlordane, DDT, dieldrin, endrin, EPN, isodrin, metacide, methoxychlor, parathion, sulphenone, and systox. All of the materials except EPN were used as emulsifiable concentrates in a water solution and applied with a gear-pump, tractor mounted sprayer. EPN was used as a wettable powder in a water suspension and applied with a hand sprayer.

Pea aphid population samples were obtained as square foot quadrates or by use of a 15-inch insect net.

A small garden tractor equipped with a 38-inch cutter bar was used to harvest the hay yield samples. The moisture content of the alfalfa was determined by placing samples of the green hay in a forage drying oven.

Methods of Procedure.—Weekly examination of the pea aphid population in the alfalfa fields of the Fort Hays Experiment Station started March 31 and were continued, except when adverse weather interfered, until April 28. The density of the population was measured by square foot quadrates on March 31, April 7, and April 14. Rainfall prohibited the sampling on April 21 but samples were obtained April 24.

The pea aphid population was measured by the use of five sweeps of a 15-inch insect net after April 24.

Following the sampling on April 28, 48 plots 80 by 100 feet in size were staked out for treatment with the emulsifiable concentrate insecticides. Eight plots 20 by 40 feet in extent were staked out for the insecticide used as a wettable powder. Population counts were obtained before application of the insecticides and on the first, third, fifth, seventh, tenth, fourteenth, seventeenth, and twenty-first days after treatment.

Hay yields were obtained by mowing three swaths 38 inches wide and 30 feet long. The green weight of the alfalfa in each swath was obtained as soon as the alfalfa was cut. From these samples 5 pound green weight subsamples were oven-dried to remove all moisture. The plot yields were computed from the green weight and the percentage loss of moisture on drying.

Results.—The examination of the field on March 31 revealed only three pea aphids in 10 square-foot quadrates. The average number of pea pahids per square foot increased to 5.9 by April 7. The alfalfa was injured by frost during this week but by April 14 the average number of pea aphids had increased to 11.8 per square foot. The alfalfa was approximately 6 inches in height on April 24 which permitted the use of the sweep net. The population of the pea aphids in the alfalfa field averaged 34.9 on April 24 when the sweep net was used. The alfalfa was deteriorating rapidly on April 28. The healthy green color of the rapidly growing alfalfa turned to pale green and

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then to light brown because of the loss of the plant juices to the hordes of pea aphids that were feeding upon them. It was at this time that the pea aphid experiment proper was started.

The average number of pea aphids present in the check plots on the day of treatment was 2824 while in the check plot on April 29, the first day after the treatment only 1557 pea aphids were found, (Table 1). This decrease was due at least in part to a change in temperature. The date before the alfalfa was treated the temperature reached 83° F. The day that the insecticide was applied the maximum temperature was 77° F. On both of these days, pea aphids were found upon the upper portions of the plant. The day following the insecticide application the temperature reached a maximum of 63° F. In addition, the sky was overcast and in the early afternoon rain started to fall. Under such conditions, fewer pea aphids were found on the upper portion of the plant than had occurred on the days before. This same situation occurred in the check plot that was paired with the EPN plots. The number of pea aphids in 5 sweeps average 2662 before application of insecticide and 1472 the first day after application of the insecticide. Even with this lower number of pea aphids in the check plot on the first day after treatment, the control given by metacide, parathion, and endrin amounted to 98 per cent. EPN and systox gave 96 per cent and 94 per cent control of the pea aphid. There was considerable drop in control with the next ranking insecticide. DDT gave only 67 per cent control on the first day after application of the insecticide. The third day after application, May 1, parathion and systox gave almost complete control of the pea aphid. There were 1487 aphids found in the check plot and only 2 and 3 in the parathion and systox plots, almost 100 per cent control. Metacide, endrin, and EPN gave 99 per cent control and DDT 94 per cent control of the pea aphid. It will be noticed that DDT gave good control of the pea aphid on the third day after application which was con-

Table 1.—Average number (average of four replications) of pea aphids taken in five sweeps of a 15 inch insect net in treated and untreated Buffalo alfalfa. Field 305. Fort Hays Experiment Station. Hays, Kansas. 1952.

Insecticide	Before Treatment		After Treatment							Total
			May							April 29–May 19
	April 28	April 29	1	3	5	8	12	15	19	
Check	2824	1557	1487	2072	1029	1073	392	135	119	7788
Metacide	3514	38	10	7	1	15	16	7	40	135
Per cent control	—	98	99	100	100	99	96	95	33	98
Parathion	3566	29	2	33	1	16	12	9	43	146
Per cent control	—	98	100	98	100	99	97	93	64	98
Systox	2746	94	3	62	2	24	6	6	26	222
Per cent control	—	94	100	97	100	98	98	96	56	97
Endrin	3440	32	12	202	36	60	14	2	28	386
Per cent control	—	98	99	90	97	94	96	99	76	95
DDT	3404	512	90	68	41	41	36	11	11	810
Per cent control	—	67	94	97	96	96	91	92	91	90
Methoxychlor	3414	831	558	721	316	351	137	56	69	3039
Per cent control	—	47	62	65	69	67	65	59	42	61
Isodrin	2554	588	1136	1084	303	251	136	23	78	3600
Per cent control	—	62	24	48	71	77	65	83	34	54
Dieldrin	3026	898	820	1726	470	478	249	34	51	4725
Per cent control	—	42	45	17	54	55	36	75	57	39
Chlordane	3444	778	1066	1502	334	988	262	81	82	5092
Per cent control	—	50	28	28	68	8	33	40	31	35
Aldrin	3178	857	1464	1661	341	607	102	32	101	5165
Per cent control	—	45	2	20	67	43	74	76	15	34
Sulphenone	2977	1259	641	2038	302	603	356	49	46	5292
Per cent control	—	19	57	2	71	44	9	36	61	32
Check	2662	1472	1387	2527	930	1133	601	110	101	8260
EPN	3072	53	20	57	28	38	20	10	22	249
Per cent control	—	96	99	98	97	97	97	97	78	97

Table 2.—Average height (average of 10 samples) of the alfalfa in the pea aphid control experiment of May 6, eight days after the application of insecticides. Buffalo alfalfa. Field 305. Fort Hays Experiment Station, Hays, Kansas. 1952.

Insecticide	Rate in Ounces per Acre	Height of Alfalfa in Inches					Per Cent Increase or Decrease
		Repl. 1	Repl. 2	Repl. 3	Repl. 4	Average	
Check	—	8.4	8.2	10.8	10.5	9.5	—
Parathion	4	12.8	14.7	14.7	14.0	14.0	47
Endrin	4	12.1	9.8	12.9	12.9	11.9	25
DDT	32	11.1	12.0	12.1	11.5	11.7	23
Systox	16	10.6	9.5	13.0	13.4	11.6	22
Metacide	4	10.3	10.4	11.4	13.2	11.3	19
Methoxychlor	32	9.7	9.9	12.4	13.1	11.3	19
Isodrin	4	9.6	8.6	12.1	13.2	10.9	15
Aldrin	8	9.6	7.3	11.7	13.9	10.6	12
Dieldrin	6	9.8	10.5	8.0	11.1	9.9	4
Chlordane	16	9.7	9.5	8.2	11.6	9.8	3
Sulphenone	16	4.4	9.7	12.8	7.4	8.6	−9
Check	—	8.4	8.3	10.1	10.0	9.2	—
EPN	8	12.9	11.9	11.0	13.1	12.2	33

Table 3.—Average alfalfa hay yields (average of three samples per plot) in the pea aphid control experiment. Buffalo alfalfa. Field 305. Fort Hays Experiment Station. Hays, Kansas. May 1952.

Insecticide	Yields in Pounds per Acre					Per Cent Increase
	Oven Dry Weight					
	Repl. 1	Repl. 2	Repl. 3	Repl. 4	Average	
Check	1457	2180	1423	1526	1646	—
Metacide	4085	3993	4969	3546	4148	152
Parathion	3339	4303	4395	3947	3996	143
Systox	2846	3374	4888	3890	3750	128
DDT	3270	3626	3936	3580	3603	119
Endrin	2961	2651	4200	3075	3222	96
Methoxychlor	1675	1629	3270	3282	2464	50
Isodrin Compound 711	1721	1767	2650	2157	2074	26
Chlordane	2249	2352	1698	1538	1959	19
Aldrin	1492	1790	2502	1997	1945	18
Dieldrin	1969	1595	2111	2111	1946	18
Sulphenone	1388	1974	1538	1090	1498	−9
Check	2169	1825	1842	1549	1846	—
EPN	4596	3356	3924	4406	4070	120

siderably higher than the control given on the first day following application. There was considerable drop to the next ranking insecticide, methoxychlor, which gave 62 per cent control. All of the insecticides that eventually were to give 90 per cent control or better were doing so by the third day after application. The other insecticides never performed satisfactorily. The seventh day after application of the insecticide, May 5, there were 1029 pea aphids found in the check plot. There was only one pea aphid found in the metacide and parathion plots and two in the systox plots. All three of these rated 100 per cent control in comparison with the check plots. The endrin and EPN treatments gave 97 per cent control of the pea aphid and DDT, 96 per cent control. The population of the pea aphid started to decrease after May 8 and by May 19 the number had decreased to 119 per 5 sweeps in the check plot. The total number of pea aphids found in the check plot from April 29 to May 19, was 7788. There were three divisions in the percentage of control obtained in the use of insecticides. The first group included those that gave excellent control of the pea aphid. Metacide and parathion each gave 98 per cent control, systox and EPN each gave 97 per cent, endrin 95 per cent and DDT 90 per cent

Table 4.—Height and yield of insecticide treated alfalfa as affected by the control of the pea aphid. Buffalo alfalfa. Field 305. Fort Hays Experiment Station. Hays, Kansas. May, 1952.

Insecticide	Total Number of Pea Aphid in 8 Days Sampling April 29–May 19	Per Cent Control	Average Height 8 Days After Treatment (Inches)	Per Cent Increase or Decrease	Average Yield Oven Dry Weight (Pounds per Acre)	Per Cent Increase or Decrease
Check	7788	—	9.5	—	1646	—
Metacide	135	98	11.3	19	4148	152
Parathion	146	98	14.0	47	3996	143
Systox	222	97	11.6	22	3750	128
DDT	810	90	11.7	23	3603	119
Endrin	386	95	11.9	25	3222	96
Methoxychlor	3039	61	11.3	19	2464	50
Isodrin	3600	54	10.9	15	2074	26
Chlordane	5092	35	9.8	3	1959	19
Aldrin	5165	34	10.6	12	1945	18
Dieldrin	4725	39	9.9	4	1946	18
Sulphenone	5292	32	8.6	−9	1498	−9
Check	8260	—	9.2	—	1846	—
EPN	249	97	12.2	33	4070	120

control. The second division included methoxychlor and isodrin which gave 61 and 54 per cent control, respectively. The third division included dieldrin, chlordan, aldrin, and sulphenone which gave 39, 35, 34, and 32 per cent control, respectively.

The alfalfa in the successfully treated plots started growing rapidly following insecticide application. Eight days after treatment, May 6, the average height of the alfalfa in the treated plots increased to a maximum of 4.5 inches in the parathion plot over the height in the check plot. (Table 2). This was an increase of 47 per cent in the height over the check plot. The height of the alfalfa in the various plots fell in four categories according to the per cent of increase or decrease. Parathion gave the greatest increase with 47 per cent. The second division included endrin, DDT, systox, metacide, and methoxychlor, which gave 25, 23, 22, 19, and 19 per cent increase, respectively. The third division included isodrin and aldrin with 15 and 12 per cent increase, respectively. The fourth division included dieldrin, chlordane, and sulphenone which had 4, 3, and minus 9 per cent, respectively. In comparison with its check plot, the EPN gave a 33 per cent increase in the height of the alfalfa. The height of the alfalfa in the EPN plots was 12.3 inches and that in its check plot. 9.2 inches.

The average hay yield for the check plot was 1646 pounds per acre, (Table 3). The highest yielding plot was metacide which averaged 4148 pounds per acre which was an increase of 152 per cent over the yield of the check plot. The yields of the various treatments fall into three ranges. At the highest range were metacide, parathion, systox, DDT, and endrin which shows an increase of 152, 143, 128, 119, and 96 per cent over the yield of the check plot. In the second category was methoxychlor which had a 50 per cent increase in yield over the check plot. The third category include isodrin, chlordane, aldrin, dieldrin, and sulphenone with 25, 19, 18, and 18 per cent increase and 9 per cent decrease in yield, respectively. The yield of the sulphenone plot was 1498 pounds per acre. The yield of the EPN plots was 4070 pounds per acre in comparison to the yield of its check plot which was 1846 pounds per acre. The EPN plots gave an increase in yield of 120 per cent over that of its check plots.

A comparison of the height and yield of the insecticide-treated alfalfa as affected by the control of the pea aphid is given in Table 4. The highest yielding treatment, metacide, had the highest per cent of control of the pea aphid. It also ranked in the top five treatments in height eight days after treatment. The second highest yielding treatment, parathion, was the second highest treatment in the percentage of control of the pea aphid. This treatment also had the greatest height

eight days after treatment. The third yielding treatment was systox which was the third ranking insecticide in control of the pea aphids. It ranked fourth in height eight days after treatment. The fourth ranking insecticide according to yields was DDT. It ranked fifth in percentage of control of the pea aphid and third in average height 8 days after treatment. The fifth ranking insecticide in yield was endrin which ranked fourth in control of the pea aphid and second in the average height of the alfalfa 8 days after treatment. It will be noted that except for endrin which was rated before DDT in the percentage control of the pea aphid, that the rank of the yield of the first five insecticide treatments and the percentage control of the pea aphids were identical. The sixth ranking insecticide treatment in percentage control of the pea aphid, height 8 days after treatment, and yield, was methoxychlor. Isodrin also rated seventh in all three categories. The EPN in the small plots rated very well in comparison with the materials in the large plots. As far as percentage control of the pea aphid was concerned, it would rate as fourth ahead of endrin and DDT, both in numbers of insects present in the sweeps and in the percentage in comparison with that in the check plots. It also would give the second highest average height eight days after treatment both in comparison with percentages in corresponding check plots and in actual height. It rated second in total yields per acre and fourth in the percentage increase over the check plot. The yield of the check plot was 200 pounds per acre greater in the small plots than for those in the check plot of the large plot series.

SUMMARY.—Aldrin, chlordane, DDT, dieldrin, endrin, EPN, isodrin, metacide, methoxychlor, parathion, sulphenone, and systox were used in an attempt to control a serious pea aphid infestation in Buffalo alfalfa on the Fort Hays Experiment Station at Hays, Kansas in 1952. The application of the insecticide treatments was made on April 28. All plots except the EPN plots were 80 by 150 feet in size. The EPN plots and the companion check plots were 20 by 40 feet in size.

Population counts were obtained before treatment and 1, 3, 5, 7, 10, 14, 17 and 21 days after treatment. The population size before treatment ranged from 1995 to 4965 pea aphids per 5 sweeps of the 15-inch insect net.

In comparison with the population of the pea aphids in the check plots 24 hours after treatment, endrin, metacide, and parathion each gave 98 per cent control. EPN 96 and systox 94 per cent control. DDT gave only 67 per cent 24 hours after treatment. The third day after insecticide treatment, parathion and systox each gave 100 per cent control, endrin, metacide and EPN each 99 per cent, and DDT 94 per cent. By then all of the insecticides that were to give good control were doing so. The seventh day after insecticide application, metacide, parathion, and systox each gave 100 per cent control, endrin and EPN each 97, and DDT 96 per cent control of the pea aphid. The best control of the pea aphid for the entire season was given by metacide and parathion, each 98 per cent. Systox and EPN each gave 97 per cent control, endrin 95, and DDT 90 per cent control. Methoxychlor and isodrin gave 61 and 54 per cent control, respectively.

The alfalfa plants in those plots giving little or no control were severely affected by the pea aphids. This effect was noticed particularly in the height of the alfalfa eight days after treatment. Treatments which gave an increase in height were paration 40, EPN 33, endrin 25, DDT 23, systox 22 per cent, and metacide and methoxychlor each 19 per cent over the height of the alfalfa in the check plots. Only the sulphenone plots produced alfalfa with less growth than that which occurred in the check plots. This height was 9 per cent shorter than the alfalfa in the check plots.

In the series of large plots, the hay yield of the check plot averaged 1646 pounds of oven dry hay per acre while the check in the small plots averaged 1846 pounds of oven dry hay per acre. The highest yielding plot was metacide which yielded 4148 pounds per acre, an increase of 152 per cent over the yield of the check plot. Other plots that yielded a considerable increase over the check plots were parathion 143 per cent, systox 128, DDT 119, and endrin 96 per cent. These were also the insecticides which gave good control of the pea aphid and which produced an increase in height in comparison with that of the check plots. In the small series the EPN plots gave an increase of 120 per

cent over the yield of its companion check plots. The control of the pea aphid and the yield of the hay followed 1, 2, 3, 4, 5 order with only one exception which was that of the fourth and fifth treatments, endrin and DDT which were reversed in order in the control of the pea aphid. In addition, the alfalfa in these plots produced the greatest increase in height during the eight days following treatment. Methoxychlor and isodrin ranked sixth and seventh in control of the pea aphid, the height eight days after treatment, and in yield. In both instances, these insecticides gave only poor to fair control of the pea aphid and were very much inferior to the other treatments in yield.

CONCLUSION.—Metacide, parathion, systox, DDT, and endrin gave good control of the pea aphid in 1952. Endrin is not available to the farmer. Metacide, parathion and systox are not safe enough to use. Therefore DDT only is available for the farmer.

The increase in yield of the alfalfa in the plots treated with these five insecticides yielded 2 to 2.5 times that of the check plot. With costs for insecticide application, at two-and-a-half dollars per acre and with hay in normal years selling at twenty-five dollars a ton, the farmer would receive a net return of eighteen dollars and seventy-five cents per acre for controlling the pea aphid.

The hot dry weather which descended over most of Kansas brought about extreme drought conditions which caused crop failures on the second and third cuttings. As a result, alfalfa hay sold for 50 dollars a ton which would double the profit on the first cuttlng, and yield 37 dollars per acre for controlling the pea aphid.

Effect of Successive Treatments of DDT on Individual Susceptibility in the American Cockroach[1]

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The development of resistance to DDT on the part of houseflies, mosquitoes and other insects has stimulated interest and concern in the general problem of insect resistance to insecticides. There is a considerable amount of literature on the subject of the building up of insect resistance to DDT through generations of artificial selection, but information on the effect of successive treatments of DDT on the same individuals of a population seems fragmental.

Reference was made by Melander (1914) to the supposed development of arsenic resistance in individual gypsy moth larvae by Glaser but this work was never published. Campbell (1926) tried to induce resistance to arsenic in silkworm larvae with negative results.

McGovran *et al.* (1939) found a temporary resistance to pyrethrins in houseflies that had received a knock-down dose of ether, acetone or kerosene-pyrethrin spray before being exposed to a higher killing dose of pyrethrins. Kono (1949) reported that prefumigation of the rice weevil with low doses of carbon bisulfide decreased susceptibility to this chemical. Sun (1947) found little change in susceptibility of the granary weevil to carbon bisulphide when specimens were pre-treated with sublethal doses.

Hoffman *et al.* (1951) reported that house flies, which had survived a twice-a-day exposure to DDT, were killed much more easily than untreated flies when subsequently exposed to a higher dose. Beard (1952) studied the effect of sublethal dosages of nicotine, pyrethrum, arsenic and DDT on the susceptibility of the large milkweed bug and larvae of the wax moth. He found that the survivors, instead of being more resistant and less variable in susceptibility than untreated insects, were equal and, in several cases, even more susceptible and more variable.

MATERIALS AND METHODS.—Purified p, p′-DDT[4] was the only insecticide used on two insects, nymphs of the American cockroach, *Periplaneta americana* (L.), and adults of the large milkweed bug, *Oncopeltus fasciatus* (Dall.). Only the re-

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[4] Geigy Company, Inc., melting point 108° C.

Table 1.—Per cent mortality of American roaches after injection of DDT suspensions.

Dosages, μg./g. Roach	Male Nymphs	Dosages, μg./g. Roach	Female Nymphs
Check	0%	Check	0%
12.7	0	13.0	10
16.0	10	20.0	30
20.0	30	27.2	40
32.0	90	36.8	60

sults on American cockroaches are reported in detail in this paper. The original culture was started in 1942 from field-collected roaches and was maintained in the laboratory with no known exposure to DDT. Egg capsules, collected at intervals, and subsequent nymphal stages were kept in a constant temperature cabinet at $79 \pm 1°$ F. and a relative humidity of 88 ± 4 per cent. These nymphs constituted the stock from which all experimental insects were taken. Potatoes and cheese were used as the standard diet for both the adults and the nymphs. Water was provided constantly.

Table 2.—The number of surviving male American roaches after successive injections of increasing concentrations of DDT. Dosage ratio $=\sqrt[3]{4}$.

Series	Dosages (μg/g. Roach)					
	2	3.2	5	8	12.7	20
	1 week interval between successive injections					
A 1	10	9	9	7	7	1
2		10	9	8	7	0
3			10	10	7	0
4				10	8	0
5					9	0
6						3
	2 week interval between successive injections					
B 1	10	10	9	9	6	1
2		10[1]	—	—	—	—
3			10	9	8	3
4				9	7	3
5					8	3
6						5
	3 week interval between successive injections					
C 1	10	9	6[2]	5	3[2]	0[2]
2		10	10	8	4	2
3			10	8	5	2
4				8	5	2
5					8	3
6						5

[1] This series was discontinued because 3 roaches escaped from the container.
[2] Results significant.

Table 3.—The number of surviving male American roaches after successive injections of increasing concentrations of DDT. Dosage ratio $=2$.

Series	Dosages (μg./g. Roach)				
	2	4	8	16	32
	1 week interval between successive injections				
A 1	10	9	9	2	0
2		10	9	2	0
3			9	4	0
4				6	0
5					1
	4 week interval between successive injections				
B 1	10	10	7	3	1
2		10	9	6	1
3			10	7	1
4				7	4
5					4

Nymphal stages of the American cockroach were used at the start of the tests, but a few of the survivors succeeded in emerging as adults before the completion of the experiment. The nymphs used at the start of any series were of the last three instars.

The injection apparatus was modeled

Table 4.—The number of surviving female American roaches after successive injections of increasing concentrations of DDT. Dosage ratio $=\sqrt[3]{2.5}$.

Series	Dosages (μg./g. Roach)					
	8	11	15	20	27.2	36.8
	1 week interval between successive injections					
A 1	10	9	6	2	0[1]	
2		10	5	2	0[1]	
3			9	2	1	
4				6	1	
5					4	
	2 week interval between successive injections					
B 1	10	8	7	5	2	1
2		8	8	3	3	0
3			9	4	3	1
4				6	4	1
5					5	3
6						3
	3 week interval between successive injections					
C 1	10	9	4	1[2]	1	
2		9	8	5	0[1]	
3			8	5	2	
4				7	4	
5					5	

[1] Results significant.
[2] Result highly significant.

after that described by Heal & Menusan (1948). The depth of insertion was regulated by a fine copper wire wound on a 27-gauge hypodermic needle to form a spiral spring. Injections were made between the fourth and fifth abdominal sternites, about half way between the middle of the venter and the left side of the insect. The needle was inserted three millimeters and at an angle of about 20° from the surface. The volume of DDT-suspension was held constant at 0.02 ml. per gram of roach. Each roach was injected with successive increased dosages on various time scales. The different dosages were made by adjusting the concentrations of DDT in the solvent and followed geometric rather than arithmetical progressions. For testing, the roaches were segregrated according to sex. Each individual was weighed to the nearest 0.01 gram and injected with a specified amount of the DDT-suspension in proportion to the body weight. The DDT-suspension was prepared from acetone solution and 0.6 per cent aqueous solution of phthalic glycerol alkyl resin[5] (by volume) so that the final preparation contained 10 per cent acetone. Carbon dioxide was used to anesthetize the insects before injection. Complete anesthetization was necessary in order to avoid bleeding.

Each experiment was started with a group of ten roaches which were individually injected with the lowest DDT concentration to be used. When survivors from this treatment were to be given the next higher dose, a new series of ten nymphs was started with this higher concentration as their first exposure to DDT. In this way new series were added to the experiment at each injection interval until a highly lethal concentration was reached.

Complete immobility was considered as the criterion of death. Observations of the number of dead roaches at each dosage level were recorded just prior to the next treatment. Within a few hours after injection, those individuals which were doomed to die became prostrate. Although DDT is a slow acting poison, an interval of one week was long enough to decide the end point of the toxicity. If roaches were still in the prostration stage prior to the next treatment, they were classified as dead since prostration consistently resulted in death.

RESULTS.—The experiment was designed to study the effects of the following factors on individual susceptibility: (1) the different time intervals between successive injections or carry-over effect, (2) the different rates for increasing the dosage, and (3) the degree of selective pressure or severity of the initial treatment.

A usual dosage mortality test was conducted to determine the approximate LD_{50} of the normal male and female nymphs. The results are listed in table 1. The LD_{50}s were estimated to be 22.5 and 30.0 micrograms of DDT per gram of roach for males and females, respectively.

Two checks, consisting of 10 male nymphs and 10 female nymphs respectively, were injected at weekly intervals with an aqueous solution containing 10 per cent of acetone and 0.6 per cent of phthalic glycerol alkyl resin (by volume). After 10 injections none had died and all individuals were apparently normal. This indicated that the injection technique and the medium used for making the DDT suspension did not produce any apparent harmful effects on the roaches.

The results of successive injections of male nymphs with dosages increasing at the rate of the cube root of four and with intervals between successive injections varying from one to three weeks are shown in table 2. Table 3 lists the results when the dosage was increased at a constant rate of two with intervals between suc-

Table 5.—The number of surviving female American roaches after successive injections of increasing concentrations of DDT. Dosage ratio $=\sqrt{2.5}$.

SERIES	DOSAGES (μG./G. ROACH)				
	8	13	20	32	50
	1 week interval between successive injections				
A 1	10	8	3	0	—
2		8	2[1]	0	—
3			7	2	0
4				3	0
5					3
	4 week interval between successive injections				
B 1	10	8	3	0[1]	
2		9	5	2	
3			7	4	
4				5	

[1] Results significant.

[5] "Triton B 1956," Rohm & Haas Company.

cessive injections set at one and four weeks. Similar results on female roaches are shown in tables 4 and 5 with dosage ratios being the cube root and square root of 2.5, respectively.

The difference between the number of survivors in those series which had received two or more injections and in the respective series which received the first injection at any particular dosage level, was used as the criterion for evaluating the change in individual susceptibility. If the difference was zero, it indicated no change in susceptibility. A positive difference indicated that resistance was built up due to previous injections and, conversely, a negative difference showed that sensitivity was increased by the previous injections. The exact test of independence for a 2 by 2 contingency table for small samples was applied to determine the

Table 6.—Percentage of surviving male American roaches after first injection of DDT.

Dosage μg./Gm.	Reference		No. of Survivors	Ave. Per Cent
	Table	*Series*		
2	2	A-1	10	100
	2	B-1	10	
	2	C-1	10	
	3	A-1	10	
	3	B-1	10	
3.2	2	A-2	10	100
	2	B-2	10	
	2	C-2	10	
4	3	A-2	10	100
	3	B-2	10	
5	2	A-3	10	100
	2	B-3	10	
	2	C-3	10	
8	2	A-4	10	92
	2	B-4	9	
	2	C-4	8	
	3	A-3	9	
	3	B-3	10	
12.7	2	A-5	9	83.3
	2	B-5	8	
	2	C-5	8	
16	3	A-4	6	65
	3	B-4	7	
20	2	A-6	3	43.3
	2	B-6	5	
	2	C-6	5	
32	3	A-5	1	25
	3	B-5	4	

Table 7.—Percentage of surviving female American roaches after first injection of DDT.

Dosage μg./Gm.	Reference		No. of Survivors	Ave. Per Cent
	Table	*Series*		
8.0	4	A-1	10	100
	4	B-1	10	
	4	C-1	10	
	5	A-1	10	
	5	B-1	10	
11.0	4	A-2	10	90
	4	B-2	8	
	4	C-2	9	
13.0	5	A-2	8	85
	5	B-2	9	
15.0	4	A-3	9	86.7
	4	B-3	9	
	4	C-3	8	
20.0	4	A-4	6	66
	4	B-4	6	
	4	C-4	7	
	5	A-3	7	
	5	B-3	7	
27.2	4	A-5	4	46.7
	4	B-5	5	
	4	C-5	5	
32.0	5	A-4	3	40.0
	5	B-4	5	
36.8	4	B-6	3	30
50.0	5	A-5	3	30

significance of difference (Fisher 1950, pp. 96–97.) Comparisons were also made between different series at the same dosage level and with the same interval between successive injections but having received different numbers of injections in their previous history. A total of 229 possible comparisons were scrutinized. Only 10 out of 229 cases, or 4 per cent, showed positive differences, none of which was significant. In 26 per cent of the cases the differences were zero. In 70 per cent of the cases the differences were negative; of these, 11 differences were significant and one was highly significant by the fourfold contingency test. All cases but three of significant differences were found in comparisons between series which had received two or more injections and later series started at the particular dosage level involved.

The data were fairly consistent in showing fewer survivors in the series which had received the greater number of

applications of DDT, regardless of the severity of initial treatment, of different time intervals between successive injections, of different rates of increasing dosages or of different sexes. The results do not show conclusively that there were more survivors in the series which had longer intervals between successive injections.

In order to determine the extent of variation of population susceptibility from week to week, the percentages of survivors after the first injection of DDT at various dosage levels and conducted on different dates were pooled from tables 2 to 5. These are shown in tables 6 and 7. The LD_{50}s were estimated to be 19.5 and 26.0 micrograms of DDT per gram of body weight for males and females, respectively. The data are in very close agreement with those in table 1. This close agreement indicates that the population susceptibility was fairly constant.

DISCUSSION.—Theoretically, for any individual organism under controlled conditions, there is a certain level of intensity of toxicant below which death does not occur, and above which the individual will succumb. This intensity of toxicant is referred to as tolerance or susceptibility. In other words, the susceptibility of an individual is represented by the smallest dose which is just sufficient to kill it. As in the case of many other biological characteristics, this tolerance value will vary from one member to another of the population. The value for even the same individual, also is likely to vary from one occasion to another as a result of uncontrolled internal or external conditions. The distribution curve of a number of individuals having each particular susceptibility might be expected to be a normal curve of error. As experiments are actually conducted, each dosage kills not only those insects requiring at least this quantity of poison, but also all of the more susceptible individuals which could be killed with a smaller dosage. The proportion of organisms affected then follows the integrated normal function. The design of this experiment was based on this hypothesis. We assume that if the survivors of a series having received one or more injections of DDT still maintain their respective inherent tolerance unchanged, then there will be no bona fide difference between the number of survivors of this series and other series having received more, none or less injections in their previous history, provided comparisons are made at the same dosage level and each series is composed of the same number of individuals at the beginning of the test.

Among a number of comparisons, a few such differences were shown to be significant by appropriate statistical tests. In a majority of cases the data showed that there were always more survivors in the series which received fewer treatments of DDT. This indicates that individual tolerances of the surviving roaches are lowered by previous sublethal exposures to DDT. That sensitization of individuals by repeated sublethal dosages of DDT actually takes place has also been reported by Hoffman *et al.* (1951) with house flies, *Musca domestica* L., and by Beard (1952) with larvae of the wax moth, *Galleria mellonella* (L.) and with the large milkweed bug, *Oncopeltus fasciatus* (Dall.)

In addition to the studies reported here, the authors also carried out a series of experiments on the adults of the large milkweed bug by topical application of DDT in acetone with weekly intervals between successive applications. Each series consisted of 25 bugs and the comparisons were analyzed by using the Chi-square test. Results similar to those with cockroaches showed that the individual tolerance was reduced by previous treatments. Moreover 77 and 27 per cent of the differences were shown to be statistically significant for males and females, respectively. Thus in the case of American roaches, if more than 10 individuals had been used in each series, a higher percentage of statistically significant differences might have been obtained.

The possibility that the increase in sensitivity of cockroaches might be caused by a carry-over of DDT from one injection to the next, was tested by varying the interval from one to four weeks in different trials. There were found to be no more survivors in series receiving repeated injections at four week intervals than in those at one week intervals. Vinson & Kearns (1952), applying 20 micrograms of DDT in dioxane solution to female American roaches, found that only 3.3 micrograms or 16.5 per cent of the total DDT still remained in the body 77 hours after injection. Thus it seems unlikely

that this sensitivity was due to the cumulative effect.

Our results might be explained by assuming that the particular biochemical system or systems involved in the detoxification reaction were impaired through a chain of physiological disturbances induced by previous DDT treatment or treatments. This theory appears to be more tenable than the assumption that considerable amounts of DDT and its metabolites from previous treatments may carry over in the tissues of the surviving roaches and interfere with the degradation or storage of subsequent applications. In other words, the sensitivity was induced by the DDT-effect rather than the actual accumulation of DDT or DDT-metabolites.

It was concluded from this study that the induction of increased susceptibility in individual American roaches as a result of repeated exposures to DDT is far more likely than the development of a more active protective system or "resistance."

SUMMARY.—The effect of successive injections of DDT on individual susceptibility was studied with nymphs of the American cockroach, *Periplaneta americana* (L.). Each series was started with ten individuals selected at random from the stock culture. Whenever survivors of previous injections were treated again at a higher dosage, a new series of ten roaches from the stock were given the same treatment. The interval between successive injections varied from 1 to 4 weeks. The difference in the number of survivors between the previously treated and previously untreated series at any dosage level was used as the criterion for estimating any change in individual susceptibility. Comparisons were also made between different series at the same dosage level and with the same interval between successive injections but which had received a different number of injections in their previous history.

The results were fairly consistent in showing fewer survivors in the group which had received a greater number of injections of DDT regardless of the severity of initial treatment, of different rates of increasing dosages, of different time intervals between successive injections or of different sexes.

It is believed that the increased sensitivity to DDT indicated by these tests was induced by a physiological change in the roaches, rather than by the physical accumulation of the insecticide in their bodies.

LITERATURE CITED

Beard, R. L. 1952. Insect resistance to insecticides. Science. **115** (2996): 608–9.

Beard, R. L. 1952. Effect of sub-lethal doses of toxicants on susceptibility of insects to insecticides. JOUR. ECON. ENT. **45**(4): 561–7.

Campbell, F. L. 1926. On the possibility of development of tolerance to arsenic by individual insects. JOUR. ECON. ENT. **19**(3): 516–22.

Fisher, R. A. 1950. Statistical methods for research workers. Edinburgh, Oliver and Boyd. 11th Ed.

Heal, R. E. and H. Menusan, Jr. 1948. A technique for the bloodstream injection of insects and its application in tests of certain insecticides. JOUR. ECON. ENT. **41**(4): 535–43.

Hoffman, R. A., A. R. Roth, and A. W. Lindquist. 1951. Effect on houseflies of intermittent exposures to small amounts of DDT residues. JOUR. ECON. ENT. **44**(5): 734–6.

Kono, Tatsuro. 1949. The influence of sublethal doses of poisonous gases on insects. I. Influence of sublethal doses on the susceptibility of the adult rice beetle, *Calandra oryzae*, to carbon disulfide. Botyu Kagaku. **12**: 19–23. English summary, pp. 24–5.

McGovran, E. R., W. N. Sullivan, and G. L. Phillips. 1939. Resistance to insecticides. (The effect of knockdown and light doses on the resistance of houseflies to pyrethrum sprays.) Soap and Sanit. Chem. **15**(8): 88–90.

Melander, A. L. 1914. Can insects become resistant to sprays? JOUR. ECON. ENT. **7**(2): 167–72.

Sun, Yun-Pei. 1947. An analysis of some important factors affecting the results of fumigation tests on insects. Univ. of Minnesota, Agricultural Expt. Sta. Tech. Bul. 177, pp. 65–9.

Vinson, Eddie B. and C. W. Kearns. 1952. Temperature and the action of DDT on the American roach. JOUR. ECON. ENT. **45**(3): 484–96.

Radioisotopes as Tracers in Plum Curculio Behavior Studies

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Laboratory and field investigations on the use of radioactive materials for activation of the plum curculio, *Conotrachelus nenuphar* (Hbst.) have been conducted for the past two seasons at the Ohio Agricultural Experiment Station. This work was begun originally with the anticipation that radioisotopes would be of value in determining the specific sites chosen by the plum curculio for hibernation. Later, when activation techniques had been developed, it was evident that radioactive substances would provide a valuable method of studying many other phases of insect behavior and ecology.

The purpose of this paper is to present methods and techniques which have been developed in the course of these investigations. Such an approach seems justifiable because of the widespread interest in radioisotopes as tracers and because of the small number of publications dealing with the activation of insects feeding upon living plant tissues.

In this paper explanations of specialized electronic equipment, physical nomenclature and units of radioactivity measurement are not given since an excellent presentation of fundamental equipment and uses of radioisotopes has been made by Jenkens & Hassett (1950) and Lindquist (1952).

SELECTION OF RADIOISOTOPES.—Radiophosphorus was the first material used and was selected because of its general usefulness in biological studies. It was soon evident that radiophosphorus was not suitable for hibernation studies because of its short effective life. After using radiophosphorus for dispersal studies in 1951 it was believed that a number of different radioisotopes would be advantageous in dispersal studies to designate various points of release.

Since it is logical to assume that elements, having radiosiotopic forms, which occur naturally in the insect would be most successful in feeding studies, a spectrographic analysis was made of the plum curculio. This analysis revealed that relatively large amounts of phosphorus, sodium, calcium, potassium and magnesium were present. In addition to these elements there was evidence of aluminum, manganese, copper, iron, silicon and strontium. Of the major elements phosphorus is the only element having a radioisotope with practical radiation characteristics.[2] The irradiated forms of the other elements are either short-lived, have weak radiation characteristics or are difficult to obtain. Strontium is the only minor element which has a radioisotope that is readily available, has a sufficiently long half-life and strong radiation characteristics. Other available radioisotopes, such as sulfur^{35}, chlorine^{36}, cobalt^{60}, zinc^{65} and iodine^{131} were tested in preliminary activation experiments with varying success. Excellent results were obtained with Co^{60} and I^{131} and good results were obtained with Ca^{45} and Zn^{65}. The radioactive zinc isotope was finally selected for activating bettles at one of five release points, used in spring dispersal studies, because its radiation characteristics were considerably different from P^{32}, Sr^{89}, Co^{0}, and I^{131}. Thus recovered insects could be analyzed for the presence of any one of the five activating radioisotopes and the exact point of release determined. It is interesting to note that certain radioelements which do not

[1] Appreciation for technical advice is due Dr. J. D. Sayre of the Ohio Agricultural Experiment Station, Dr. D. W. Jenkins and Dr. C. C. Hassett of the Medical Division, Army Chemical Center, Maryland.

[2] Since it was preferable to determine insect radioactivity in the field with a portable beta-gamma survey meter, it was necessary to use materials with strong radiations.

Table 1.—Characteristics of various radioisotopes used in activation of plum curculio.

ISOTOPE	HALF-LIFE[1]	ENERGY OF RADIATION[1] (MEV)[2]		CHEMICAL FORM
		Beta	Gamma	
Phosphorus 32	14.3 days	1.71	None	$KH_2P^{32}O_4$ $H_3P^{32}O_4$
Cobalt 60	5.3 years	0.31	1.10 1.30	$Co^{60}Cl_2$
Zinc 65	250 days	0.4	1.14 0.44	$Zn^{65}Cl_2$
Strontium 89	55 days	1.5	None	$Sr^{89}Cl_2$ $Sr^{89}(NO_3)_2$
Iodine 131	8 days	0.6	0.367 0.80	Elemental I^{131} in weak Na_2SO_3 solution

[1] Lapp and Andrews, *op. cit.*
[2] Million electron volts.

normally occur in the plum curculio are so easily ingested and persist so long in the insect. The physical characteristics of the five radioisotopes used in dispersal and hibernation work appear in table 1.

Phosphorus ^{32} in the form of potassium acid phosphate was ordered as a 31 gram unit having a total activity of 350 millicuries (mc.).[3] Since this type of P^{32} is not processed, there is some variation in the amount of activity. In six shipments of radiophosphorus from November 15, 1950 to April 14, 1952, the total activity varied from approximately 342 to 485 mc. per unit. The 31 grams of phosphate were dissolved in 500 or 1000 milliliters (ml.) of distilled water in a volumetric flask.

Processed phosphorus was used only in preliminary work because of its relatively high cost. This material was received as orthophosphoric acid having a concentration of 3.87 mc./ml. on October 23, 1950.

Cobalt^{60} was received as cobalt chloride in acid solution having an original concentration of 34.2 mc./ml. ± 3 per cent. This amount was transferred to a volumetric flask and distilled water was added to make 20 ml. The final concentration of the stock solution was 1.020 mc./ml. on May 7, 1952.

Zinc^{65} was obtained as 6.4 ml. of zinc chloride in acid solution having an original concentration of 3.14 mc./ml. ± 10 per cent on April 11, 1952.

Strontium^{89} was received in two distinct forms and these varied widely in specific activity. One unit of Sr^{89} in the form of strontium nitrate with a total activity of approximately 1.5 mc. was received on August 16, 1951. The unit, weighing 32.9395 grams, was dissolved in distilled water and made up to 250 ml. as a stock solution. The other shipment of Sr^{89} contained 31.3 ml. of strontium chloride in acid solution having a concentration of 1.60 mc./ml. ± 10 per cent on April 10, 1952.

Iodine^{131} was received as a 50.435 mc. unit having a concentration of 9.17 mc./ml. ± 10 per cent. This was made up into a stock solution of 50 ml. with a concentration of 0.25 mc./ml. on May 1, 1952.

METHODS OF ACTIVATING INSECTS.—*Topical application.*—Attempts at topical application by immersing curculios into aqueous solutions of processed H_3PO_4 with an activity of 4.5 microcuries (μc./ml.) were unsuccessful even though wetting and sticking agents were added. This method has not been fully investigated and may be quite practicable if high specific activity solutions can be combined with water soluble paints or adhesives. Another procedure, which involved the application of P^{32} solutions to the dorsal surface of the abdomen beneath the elytra, was unsuccessful because so many insects were injured in the mechanical process of lifting the elytra.

Feeding.—Two general methods were used in an attempt to feed radioactive materials to plum curculios. First, radioactive solutions were transferred to shell vials and stoppered with moist cotton plugs. In the late summer and fall of the year when beetles are relatively inactive they ingested readily radioactive liquid from the moist cotton. In the spring, however, bettles are much more active and thrive better if both food and water are supplied during the activation period. Food was provided in the form of succulent peach terminals placed in small water bottles. When foliage was provided, the the insects no longer visited the shell vials and therefore it became necessary to activate the foliage and to remove the vials. Radiophosphorus and radiostrontium were absorbed quickly by peach foliage and beetles feeding upon such foliage became highly radioactive in a few days. Radiozinc at concentrations comparable to the preceding elements proved extremely toxic to the foliage. When lower dosages of Zn^{65} were employed, plum curculios feeding upon the foliage were only moderately activated. Attempts to produce radioactive foliage with radiocobalt and radioiodine were unsuccessful. This was probably due to selective absorption and distribution of these materials in the plant tissue. Sayre (1952) has shown that Co^{60} is not evenly distributed in corn leaves but accumulates in large quantities at the leaf margin.

In P^{32} activation experiments with solutions a concentration range of from 2.5 to 363 μc./ml. was tested over a period of two years. The optimum dosage, when using shell vials, appeared to be around 50 μc./ml. Plum curculio adults

[3] The radioactive substances used in these experiments were obtained from the Isotopes Division, United States Atomic Energy Commission, Oak Ridge, Tennessee.

exposed to this concentration of P^{32} for 5 days averaged approximately 50,000 counts per minute (cpm.). The activity, measurable with a decade scaler having about 10 per cent geometry, persisted for approximately 120 days. These data are based upon tests conducted from August 21 to December 17, 1951. In the spring of the year when physiological processes in the beetles are more active the retention time of radiophosphorus is probably greatly reduced. When the concentration of P^{32} is increased, a given activity is reached in a shorter time, but concentrations in the range of 350 μc./ml. proved to be toxic to adults. When peach foliage was employed to activate beetles, concentrations of from 10 to 122 μc./ml. were tested. The lower ranges resulted in activities of from 1,900 to 10,000 cpm. per beetle in 5 days as compared with an activity of 14,000 cpm. in the upper ranges. The optimum concentration was considered to be approximately 100 μc./ml. At this strength beetles reached high activities in four to five days.

Radiocobalt was the most persistent of the five radioisotopes tested and therefore lends itself particularly well to hibernation studies. It was concluded from preliminary experiments carried on in the spring of 1952 that a radioactive cobalt chloride solution at a concentration of 100 μc./ml. gave adequate activation. Beetles feeding upon such solutions averaged about 12,000 cpm. in 5 days. Attempts to activate peach foliage with Co^{60} solutions were unsuccessful.

In the fall of 1951 Co^{60} solutions with concentrations of 5.5, 11, 22 and 44 μc./ml. were compared. Four days after exposure the respective average activities of the insects were 1915, 2476, 5489 and 6645 cpm.

Preliminary tests with Zn^{65} at concentrations of 2, 4, 8 and 16 μc./ml. indicated that much higher ranges would be needed for field recoveries. Accordingly, the concentration was raised to 290 μc./ml. but this concentration proved toxic to beetles. Concentrations of 44 μc./ml. killed succulent peach foliage very quickly. When this solution was reduced to half strength, fair activities were obtained in beetles feeding upon activated foliage. A group of 21 insects which had fed upon activated foliage at the above concentration averaged 758 cpm. This material was the least effective of the five radioactive materials employed in feeding tests. If effective topical application techniques can be developed, radiozinc may be an effective material since it has rather distinctive radiation characteristics.

Initial experiments with radiostrontium were carried on with $Sr^{89}(NO_3)_2$ at concentrations of 0.375, 0.75, 1.5 and 3 μc./ml. After curculios had reached a count of several hundred counts per minute they exhibited symptoms of poisoning and died within a few days. Later tests with the non-radioactive salt, Sr^{88} $(NO_3)_2$, proved that typical symptoms of poisoning were produced by chemical, rather than radiation, effects.

The following year, solutions of $Sr^{89}Cl_2$ of high specific activity and comparatively low chemical concentrations were used successfully in both foliage and vials. Relatively low levels were used successfully in both foliage and vials. Relatively low levels of activity of $Sr^{89}Cl_2$ are needed to produce high activity in the plum curculio. The optimum concentration was approximately 2 μc./ml. in vials and 20 μc./ml. in foliage.

Radioiodine was employed in concentrations of 8, 32, 40 and 75 μc./ml. in activation work. At the higher concentrations beetles after 5 days exposure averaged 26,864 cpm. while at lower levels they averaged 2,680 cpm. I^{131}, like Co^{60}, was not readily absorbed by peach foliage and therefore aqueous solutions in vials were used in all activation work.

DISCUSSION.—Five different radioisotopes, P^{32}, Co^{60}, Zn^{65}, Sr^{89} and I^{131}, were employed in spring dispersal studies of the plum curculio in 1952. These materials were used to designate five different release points. Five separate releases were made at each point at weekly intervals from May 12 to June 15. Curculios were liberated at the base of the release tree in early morning or after sun down. Tagged beetles were recovered by jarring all trees in the orchard at about 3 to 4 day intervals. Beetles, which were collected in this manner from release trees were checked for radioactivity with an Electronic portable beta-gamma survey meter. Individuals showing activity were recorded and released with the assumption that the identity of the radioisotope in the insect corresponded with that of the release point. Plum curculios which were re-

covered after they had flown at least 25 feet from the point of liberation were brought into the laboratory and measured for radioactivity in a Berkeley Decimal Scaler. Radioactive insects were then killed and cemented to the bottom of a metal counting planchet. Next an attempt was made to determine the point of release by identifying the radioisotope present in the insect on the basis of its radiation characteristics. First, the relative energy of the radiation was determined by means of a graduated series of aluminum foil absorber screens. Absorption curves were then prepared and in this manner the pure beta emitting materials could be separated from the beta-gamma emitting isotopes. Counts were then made at 14-day intervals for half-life determinations. Release points were determined for 93 per cent of the beetles recovered at various points in the orchard. Table 2 shows the number of beetles released, the number of beetles recovered and the average flight distance.

The relative efficiency of various materials is evident in the number of insects released since radioisotopes which gave the best activation were most frequently used. The total number of recoveries is somewhat misleading due to the fact that the five liberation points were assigned to every other tree in a border row. Thus trees on each end of these five points would be placed at a disadvantage and those in the center would be placed at an advantage in per cent of recovery. The respective arrangement of release points was Co^{60}, Zn^{65}, P^{32}, Sr^{89} and I^{131}.

A total of 31 beetles was recovered on trees exclusive of the release trees. No recoveries were made of insects activated with radioiodine or radiozinc on other than the release trees. This is believed to be due to the short half-life of radioiodine and because of the small number of insects activated with radiozinc.

There is considerable variation in the average distance flown by insects activated with different radioisotopes. A further comparison of tables 1 and 2 indicates that the shortest flight distances are associated with the shortest half-lives. Since these figures are based upon relatively small numbers, they are not significant although there is an indication that there is a half-life effect in this particular experiment.

In the fall of 1951 a hibernation study of plum curculio was conducted in a sod peach orchard at East Harbor State Park. Because of its persistence as a tagging material Co^{60} was employed for this work. A group of 678 beetles was exposed to vials containing solutions of radiocobalt chloride at a concentration of 22 μc./ml. After a 13-day exposure to the radioactive solutions, 50 beetles averaged 9410 cmp. On September 26 these insects were released uniformly throughout the orchard at the rate of four beetles per tree. A week after the liberation, activated insects could be found rather easily near the point of release even when the probe of the survey meter was several inches from the insect. No beetles could be detected the following spring with the survey meter since the levels of activity were such that they could not be detected at a distance greater than an inch.

The jarring of peach trees in this orchard at periodic intervals during the period of spring brood activity yielded a total of 1260 plum curculios of which 59 were radioactive. Insect radioactivity, in this case, was determined by means of a decade scaler in the laboratory. The activity of the recoveries ranged from 52 to 1247 (background 17 to 19 cpm.). From April to the end of May recovered beetles averaged 300 to 400 cmp. As late as June 11 activities averaged about 140 cpm. All recoveries were caged and observed at intervals until death. As far as could be determined no chemical or radiation effects were evident. Some beetles lived to as late as July 8 which was 287 days after activation and release.

Although Co^{60} was useful in this experiment because of its persistance, it is believed that more efficient techniques can be developed. The material did not retain radiation of sufficient intensity to register

Table 2.—Release, recovery and flight distance of plum curculios marked with various radioisotopes.

Radioisotope	Beetles Released	Beetles Recovered	Average Flight Distance in Feet
P^{32}	62	48	40
Co^{60}	127	50	118
Zn^{65}	23	5	0
Sr^{89}	175	75	113
I^{131}	86	17	0

on a portable survey meter at a distance greater than one inch after several months and therefore exact sites of hibernation could not be determined. The pattern of recovered beetles, however, indicated that most of the beetles hibernated within the orchard.

SUMMARY.—Radiophosphorus, radiostrontium and radiocobalt were useful in spring dispersal studies of the plum curculio. However, the usefulness of radiophosphorus was somewhat limited either because of its relatively short half-life or because of its rapid excretion by activated insects. Beetles were tagged readily by allowing them to feed upon peach terminals immersed in radioactive solutions of P^{32} and Sr^{89}. This method failed to produce adequate activity with Co^{60} and I^{131} and was only moderately successful in the case of Zn 65. Highly radioactive insects were produced by exposing beetles to radiocobalt and radioiodine solutions in cotton stoppered shell vials. Radiocobalt activated insects which were released in a peach orchard in September retained activity for approximately 8.5 months. These insects were not sufficiently radioactive to be detected with a portable survey meter at a distance greater than 2 inches.

LITERATURE CITED

Jenkins, D. W. and C. C. Hassett. 1950. Radioisotopes in entomology. Nucleonics **6**(3): 5–14.

Lapp, R. E. and H. L. Andrews. 1950. Nuclear radiation physics. Prentice-Hall, Inc. New York.

Lindquist, A. W. 1952. Radioactive materials in entomological research. JOUR. ECON. ENT. **45**(2): 264–70.

Rings, Roy W. 1952. Fruit insect behavior studies aided by radioisotopes. 70th Annual Rpt. Ohio Agr. Expt. Sta. Bul. **725**: 59–60.

Sayre, J. D. 1952. Accumulation of radioisotopes in corn leaves. Ohio Agr. Expt. Sta. Res. Bul. **723**: 1–30.

Continuous Laboratory Propagation of Western Grape Leaf Skeletonizer and Parasites by Prevention of Diapause[1,2]

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A program for biological control of the western grape leaf skeletonizer, *Harrisina brillians* B. & McD., was initiated in 1950 by the University of California Department of Biological Control, Riverside. Exploration for natural enemies was conducted in Arizona and New Mexico and the states of Sonora and Chihuahua, Mexico, in 1950, and throughout most of the other states of Mexico and in the eastern United States in 1951. Ten species of parasites native or adaptable to *H. brillians* were found during these two years. Two diseases of the skeletonizer also were discovered, one caused by a spore-forming bacillus and the other by a granulosis virus.

All the parasites have been studied and six species have been evaluated as meriting propagation for field release. Experimentation has been carried on in a greenhouse at La Mesa, California, within the infested area of San Diego County, thus complying with state quarantine regulations.

Under natural conditions *Harrisina brillians* and its parasites spend 6 months in diapause during the fall, winter, and early spring. Simultaneously, grapes are dormant in the field in southern California. As prerequisites to biological studies and/or propagation of these insects throughout the year, both of which require a steady supply of all stages, diapause had to be manipulated or prevented and grape foliage had to be grown for food during the winter. The present study consisted of two distinct phases, the first relating to the prevention of diapause or to the factors inducing inception of diapause in the host species and its parasites, and the second relating to the factors

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[2] Presented at the meeting of the Pacific Slope Branch of the American Association of Economic Entomologists, Santa Barbara, California, June 26, 1952.

influencing the breaking of diapause.

During the effort to overcome the diapause of these insects, important facts were brought to light concerning the adaptability of *Harrisina brillians* and two of its parasites, an undescribed *Apanteles* temporarily designated as *Apanteles* sp. "A", and *Sturmia harrisinae* Coq., to climatic extremes in California. Because this experimentation was for practical propagation purposes rather than for the investigation of diapause alone, results are in some cases incomplete but are nevertheless indicative. Results of the biological studies on most of the parasites thus far discovered, and evaluations of their effectiveness in the field, will be reported later.

DIAPAUSE.—The extensive literature on diapause in insects falls into three general categories: (1) the physiology or nature of diapause, (2) factors governing inception of diapause, and (3) factors influencing breaking of diapause. A recent and thorough review of the literature of diapause is that of Andrewartha (1952), who discusses the earlier theories of the physiology of diapause and advances a new hypothesis attributing diapause to "the accumulation of 'intractable' stores of food materials in the tissues of the diapausing individual." Excellent reviews appearing at earlier dates are those of Dickson (1949) (induction of diapause) and Prebble (1941).

Diapause is defined by Andrewartha (1952) as "a stage in the development of certain animals during which morphological growth and development is suspended or greatly retarded." It is an adaptation of a certain resistant stage in the life cycle which enables species to persist despite the rigors of adverse climate. Diapause is of two types, obligate and facultative, the former usually in univoltine species and the latter usually in multivoltine species. Obligate diapause appears to be inherited and independent of ordinary variations in the environment. Facultative diapause arises in response to appropriate stimulus from the environment.

Factors Governing Inception of Diapause.—Several different environmental factors, alone or in combination, have been shown to influence the induction of diapause in Lepidoptera and other insects. For example, in the corn earworm, *Heliothis armigera* (Hbn.), diapause is induced by low temperature during the larval feeding period (Ditman *et al.* 1940); in the oriental fruit moth, *Grapholitha molesta* (Busck), and in the codling moth, *Carpocapsa pomonella* (L.), it is controlled by temperature and photoperiod (Dickson 1949); and in the pink bollworm, *Pectinophora gossypiella* (Saund.), it is independent of the season and depends upon the moisture content of the seed in which the larvae feed (Squire 1937).

Factors Influencing Breaking of Diapause.—Resumption of development after diapause in lepidoterous insects is promoted by a number of factors, and several artificial devices have been employed for shortening or breaking diapause. The need of exposure of definite duration at below developmental temperatures has been demonstrated for the European corn borer, *Pyrausta nubilalis* (Hbn.), by Babcock (1924), and for the eastern tent caterpillar, *Malacosoma americanum* (F.), and the fall cankerworm, *Alsophila pometaria* (Harr.), by Flemion & Hartzell (1936). The importance of contact moisture during the normal diapause period of the European corn borer (Babcock 1924, 1927), or at the time of normal cessation of diapause in the ragweed borer, *Epiblema strenuana* (Wlkr.) (Rice 1937), the codling moth (Townsend 1926), and the pink bollworm (Squire 1937, 1939) has been pointed out. Pepper (1937) was able to re-stimulate activity of the dormant beet webworm, *Loxostege sticticalis* (L.), by fumigation for 6 hours with xylol (0.016 cc. per l.). Examples of activization by mechanical shock, such as by wounding and singeing of the greenbottle fly, *Phaenicia* (*Lucilia*) *sericata* (Meig.), have been reported by Roubaud (1922).

MATERIALS AND METHODS.—For studies of the first phase, namely, the prevention of diapause in *Harrisina brillians* and its parasites, larvae of *H. brillians* were cultured on Thompson Seedless grapevines growing in 10-quart galvanized pails set on greenhouse benches. Propagation colonies of larvae were reared under a 15-hour day (ratio of hours of light to hours of darkness, 15:9), with daylight augmented, as necessary, by artificial light of a minimum intensity of 10 foot-candles and a maximum of 80 foot-candles, the amount of illumination depending upon the location of the vines on

the benches. Supplementary light was supplied by 150-watt incandescant bulbs wired in series to a Paragon 10-ampere automatic time switch. Comparable colonies of larvae were reared under conditions of 11.5 to 13.5 hours of daylight (twilight excluded), with no artificial illumination. Light intensity was measured with a photometer.[3]

For studies of the second phase, or of factors influencing the breaking of diapause, large collections of full-grown larvae of *Harrisina brillians* were made in the late summer in Chihauhua, Mexico,[4] Arizona, and California.[5] All larvae had an approximately uniform pupation date of October 1. After this transformation, pupae, which had been divided into lots, were subjected to different climatic conditions, including (a) varying periods of cold duration and intensity, both fluctuating and constant; and (b) different moisture relations, both outside and inside the laboratory, ranging from atmospheric humidity, only, to 24-hour immersion in water, followed by saturated environments. Separate tests were conducted with xylol fumigation and with physical mutilation of pupae, either by puncturing with a fine needle or by singeing. Climatological data of the United States Weather Bureau were used in making comparisons of pupae exposed out-of-doors during their overwintering treatment.

Insects used in the first-phase studies were held exclusively in the laboratory. For the second-phase studies, part of the insects were kept in the laboratory; others were brought in after field exposure or refrigeration. During part of this experimentation there were occasionally wide fluctuations in greenhouse temperatures and humidity, temperatures ranging from 45° to 100° F., and R.H. ranging from 10 to 80 per cent. Pressure of work demanded proceeding, however, despite early inadequate laboratory conditions. Later, temperature was maintained at approximately 75° F., and R.H. varied, in general, between 50 and 70 per cent.

DISCUSSION OF RESULTS.—*Inception of Diapause in Harrisina brillians and Its Parasites.*—In the field the western grape leaf skeletonizer has two full generations and a possible third brood. It enters diapause from mid-September to November, the time depending upon the location, and the moths emerge in the spring from late April onward. Thus a minimum of about 6 months is normally spent in diapause. Photoperiod is the dominant and probably the sole environmental factor controlling induction of diapause in this species. This photoperiodic effect is produced during the larval feeding period.

In the laboratory, when reared under a 15-hour day, *Harrisina brillians* did not enter diapause. With increasing darkness (*i.e.*, when hours of darkness exceeded 10.5), the larvae entered diapause. This was equally true in the fall, with decreasing hours of day-length, and in the winter and spring, with increasing hours of day-length. For example, 100 per cent of the larvae entered diapause and no moths emerged throughout the summer, although adequate moisture was supplied, when larvae were reared under daylight alone during March and April, with ratios of hours of light to darkness ranging from 11.6:12.3 to 13.5:10.5. Dickson (1949) found that the darkness-induced phase of the photosynthetic-type reaction causing diapause at medium temperatures in the oriental fruit moth "is extremely sensitive to the length of the period of darkness and does not reach its effective point unless there are at least 11 hours of darkness per 'day.' " Although no effort was made to determine precisely the critical period of light or darkness inducing diapause in *H. brillians*, it appears to be very similar to that for the oriental fruit moth.

Field observations indicate that same phenomenon. Counts for two years showed that 99 per cent of the larvae developing through the last week of August onward, after hours of darkness increase to 10.5 or more per day, entered diapause. The 1 per cent that emerged in the fall could be holdovers from shorter periods of darkness.

The exact stadium in which larvae are most sensitive to the photoperiodic stimulus was not determined. It was observed, however, that one group of larvae uniformly entered diapause when reared under a 15-hour day except during one week when the ratio of light to darkness was reversed (*i.e.*, 9 hours of light to 15

[3] Model 614; Weston Electrical Instrument Corporation.
[4] Pupae from Mexico were held in quarantine in Riverside.
[5] Only larvae from Arizona and Mexico were parasitized—no parasites were then present in California.

hours of darkness) while the larvae were in the late fourth and early fifth instars. In contrast, another group did not enter diapause when the only variable from the above was that the ratio of light to darkness for the one week was 12:12. This seems to indicate that the photoperiodic stimulus may affect any larval stadium and that a certain number of hours of darkness may be a factor in bringing the dark-phase reaction to completion, thus inducing diapause.

The stage affected appears to vary between species. Dickson (1949) found that the photoperiod is operative during all the larval feeding period of the oriental fruit moth, but that the early part of the period is more critical than any other part. Komarova (1949) shows that in the grapevine leaf-roller, *Polychrosis botrana* Schiff., the egg is most sensitive to photoperiod, with progressive decline in responsiveness in the first and second larval instars and with none at all in the third and fourth.

It was also observed that the intensity of the diapause-inducing reaction was not uniform in *Harrisina brillians* and that after a definite minimum duration of diapause a few individuals of the populations were able to overcome the effects in a comparatively short time. This seems to account for staggered emergence under identical environmental conditions. Moreover, there were indications of the existence of a diapause-strain, never exceeding 15 per cent and generally not appearing, which entered diapause under apparently "optimal" exposure to light (15:9). Because such exposure completely prevented diapause in most of the populations, this is further evidence of individual variation in response to the diapause-inducing stimulus.

Artificial light of 10 foot-candle intensity and apparently as low as 5 foot-candles, when used to augment daylight, was definitely effective in preventing diapause in *Harrisina brillians*.

The masking effect of both high and low temperatures upon the photoperiodic influence noted by Kogure (1933) in the silkworm, *Bombyx mori* (L.), and by Dickson (1949) in *Grapholitha* was not evident in *Harrisina brillians*. This suggests the possibility that the effects of alternating (variable) and constant temperatures are not the same. Moreover, there was no indication that either high or low temperatures influence inception of diapause in the western grape leaf skeletonizer in any other way.

Near-threshold temperature (50° F. constant) arrests development of all stages of *Harrisina brillians*. Eggs will endure up to 120 hours of this temperature and thereafter develop normally when restored to laboratory temperature, their hatching being slowed in proportion to refrigeration time. Third- and fourth-instar larvae were paralyzed by this temperature but survived and developed normally upon return to heat after 1 week of exposure. In neither case did diapause occur. Longer exposure to both stages was fatal. Prepupae cannot transform and were killed during 5 weeks of 50° F. temperature. In contrast, slightly older specimens from the same larval colony (pupae), all of which had been reared in the laboratory under the 15-hour day. survived this treatment and thereafter emerged within normal pupal limits. What effect if any gradual lowering of temperature during the larval feeding period might have was not ascertained. Likewise, moisture content of the leaves did not appear to affect diapause.

Apanteles sp. "A" overwinters as a full-grown larva in its cocoon within the host cocoon, while *Sturmia* passes the period of host diapause as a first-instar larva within the host pupa. It was not made clear what physical factor or factors may control the cessation of parasite activity or diapause, or whether biotic factors such as changes in host physiology accomplish this. For the purposes of the present study it has been sufficient to know that when the host enters diapause in the fall its parasites also enter diapause, and that continuous generations of *Harrisina brillians* in the laboratory produce uninterrupted broods of the parasites. Emergence records of field-collected material indicate, however, that the parasites may enter a true diapause, which, like that of the host, requires a definite time factor before morphogenesis will resume.

"Breaking" of Diapause in Harrisina brillians and Its Parasites.—None of many variations of the methods suggested in the literature on diapause resulted in shortening the diapause of *Harrisina brillians*. With this insect as with the oriental fruit moth, once diapause begins, a definite

Table 1.—Relation of aridity and temperature to survival of *Harrisina brillians* during diapause.

Lot	Total Number of Pupae	Days Pupae Dry (Before Contact Moisture)			Temperature, °F.			Days With Freezing Temperature[2]	Per Cent Survival
		In Field	In Laboratory	Total	Maximum	Minimum	Av.[1]		
2A	266	67	100+	167+	100	40	67.5	0	17.7
2B	1211	67	60	127	100	40	66.2	0	21.4
1	867	67	51	118	100	20	60.7	30	45.1
8	469	67	30	97	100	40	63.3	0	55.0
7	230	67	30	97	100	20	60.3	30	59.1
12	1103	148	0	148	85	13	53.8	60	78.9

[1] Average of field and laboratory temperatures.
[2] Number of days during which temperature fell to freezing or below.

time interval is required, regardless of external conditions, before developmental activity is resumed. The photoperiodic effect has a minimum duration of 120 days. Favorable humidity relations accelerated even-broodedness and gave peak emergences but were not effective until after the time element was satisfied. On the basis of this finding, it is assumed that moths might emerge in the field after 4 months rather than after 6 months, other factors being propitious.

With *Apanteles* sp. "A", except for cocoons brought into the laboratory late in May (near the normal emergence time), a minimum of about 35 days was required for first emergence, and of 45 to 50 days for peak emergences. Fifty or more days of laboratory heat were required for first emergence from cocoons brought in during the winter, regardless of other treatment. Response to inside temperature was much more marked in the case of *Sturmia*, with which emergence began in about 30 days at the onset of winter, the period becoming correspondingly shorter for material brought in as the seasons advanced, requiring 12 days in early March and 7 days in late May. Despite these facts, less is known about the "diapause" of these parasites than of their host. *Apanteles* apparently enters a true diapause, while with *Sturmia* it is doubtful.

Climatic Factors Affecting Winter Survival of Host and Parasite.—In the course of the effort to rupture or shorten the diapause of *Harrisina brillians* and its parasites for propagation purposes, a considerable quantity of data accumulated pertaining to the relation of climate to winter survival of the species involved. Because of the practical nature of the experimentation, the factors under investigation were not always reduced to a single variable. For the sake of brevity, only representative tabulations are given below, although certain data are presented in more than one table to facilitate comparison.

The relation of aridity and temperature to survival of *Harrisina brillians* during diapause is shown in table 1. During "cold rest" (outside exposure of diapausing insects), the pupae of Lots 1, 7, and 12 were held all or part of the time, in the fall or winter, at 6000 feet elevation; the remaining lots were exposed to fall coastal temperatures, at 500 feet elevation, only. Examination of the data reveals that (1) a low percentage of moths (17.7 per cent in Lot 2A) survived diapause in complete absence of contact moisture; (2) an inverse correlation exists between survival and aridity at high temperatures during diapause (shown by the fact that the greater the period of time pupae were held in the laboratory before receiving contact moisture, the greater was the mortality); and (3) high mortality is associated with high evaporation rate, since much higher survival resulted despite more extended aridity at cool temperatures (Lot 12).

Aridity is here defined as the absence of contact moisture. Inasmuch as Babcock (1924, 1927) has shown that atmospheric moisture is useless in breaking the diapause of the European corn borer and that winter mortality in this species is correlated with the duration of aridity, and Prebble (1941) has demonstrated that the benefit derived by the European spruce sawfly, *Diprion* (*Gilpinia*) *hercyniae* (Hgt.), from contact moisture during diapause is lost as the result of evaporation

Table 2.—"Cold-rest" moisture in relation to survival of *Harrisina brillians*.

Lot	Total Number of Pupae	In the Field					In the Laboratory[1]		Per Cent Survival
		Total Days	Moisture (Inches of Rain)	Temperature, °F. Minimum	Temperature, °F. Av.	Days with Freezing Temperature[2]	Initial Moisture Treatment[3]	Subsequent Moisture	
5A	2712	156	4	5	43.2	98	None	None	69.4
5B	2712	156	4	5	43.2	98	6-hr. soaking	Wet sand[4]	55.3
14B	1200	151	3	19	50.0	48	None	None	79.6
14A	1200	151	3	19	50.0	48	24-hr. soaking	Wet sand[4]	80.3

[1] Laboratory temperatures averaged 75° F.
[2] Number of days on which temperatures dropped to 32° F. or below.
[3] On first day in laboratory.
[4] Water-saturated environment.

unless the insects are held at 100 per cent R.H., atmospheric moisture has been discontinued in consideration of the present data. Moreover, as has been mentioned, even-broodedness of *Harrisina brillians*, after the diapause time element has been satisfied, is directly affected by moisture relations during diapause. Pupae receiving ample water during cold rest or soon after being brought into the warm laboratory demonstrated consistent peaks of emergence, while those receiving little or not contact moisture produced protracted and staggered emergence requiring much greater over-all time.

The data presented in table 2 give an indication of the relation of "cold-rest" moisture to the survival of *Harrisina brillians*, and also of the effects of over-extended cold. Lots 5A and B were exposed from October 15, 1950, to January 15, 1951, at an elevation of 8500 feet, and for the remaining 59 days at 1500 feet. Lots 14A and B spent 4 months at 6000 feet and the other 28 days at the lower elevation. Unfortunately, no control lot was run, receiving no contact moisture during cold rest. The data indicate, however, that the quantity of contact moisture received during cold rest does not need to be great to produce heavy survival, and that contact moisture received during cold rest is utilized by the pupae in diapause. They also indicate that if adequate moisture is received during cold rest additional moisture during the period when the insects are in the laboratory, which corresponds roughly to the spring emergence period, may have a deleterious effect upon survival (Lot 5B), and that over-extended cold may likewise have an adverse effect upon survival.

The harmful effect of cold of too great a duration or intensity is again indicated in table 3. Lot 13 was exposed for 5 months at an elevation of 6000 feet, and the rest of the time was equally divided between 1500- and 500-foot elevations. The relatively high mortalities which occurred in Lots 2B, 8, and 7 were earlier attributed to aridity (Table 1), but because the cold exposure of these treatments was comparatively mild, they are included here. They help to demonstrate that within certain limits cold weather during diapause did not impair survival of *Harrisina brillians* but rather appears to have aided survival. Comparison of the remaining lots, on the other hand, indicates that cold may have a harmful effect upon survival if of too great a duration, or even more likely, if of too great an intensity.

It is obvious from the data of table 3 that *Harrisina brillians* is a cold-hardy insect. This characteristic, together with hardiness in other respects, is demonstrated by the following experimental results: 58 per cent survival occurred after 3 weeks of constant freezing temperature (32° F.), when a gradual warm-up period of 1 week followed (sudden change from freezing to laboratory temperature proved fatal in most cases); 80 per cent survival occurred after xylol fumigation; and 58 and 78 per cent after puncturing and singeing, respectively.

Table 3.—Relation of cold duration and intensity to survival of *Harrisina brillians* in the field.

Lot	Total Number of Pupae	Total Days of Exposure	Temperature, ° F. Minimum	Temperature, ° F. Av.	Days With Freezing Temperature[1]	Per Cent Survival
2B	1211	67	40	57.5	0	21.4
8	469	67	40	57.5	0	55.0
7	230	67	20	53.2	30	59.1
14B	1200	151	19	50.0	48	80.3
12	1103	235	13	53.8	60	78.9
13	521	235	13	50.1	90	73.2
5A	2712	156	5	43.2	98	69.4
5B	2712	156	5	43.2	98	55.3

[1] Number of days on which temperature dropped to 32° F. or below.

Table 4.—Relation of aridity and temperature to survival of the parasite *Apanteles* sp. "A" during diapause.

Lot	Total Number of Cocoons	Days Cocoons Dry (Before Contact Moisture)			Minimum Temp. °F.	Days with Freezing Temp.[1]	Contact Moisture			Per Cent Survival
		In Field	In Laboratory	Total			In Field (Inches) of Rain)	In Laboratory[2]		
								Initial Treatment[3]	Subsequent Treatment	
1	1082	67	51	118	20	30	0	None	Dipping[4]	16.45
13	2227	148	0[5]	148	13	90	4.68	6-hr. soaking[6]	Damp	43.70
14B	2400	95	—	95	19	48	3	None	None	59.00
14A	2400	95	0[5]	95	19	48	3	24-hr. soaking[6]	Wet sand[7]	66.50
5A	459	75	—	75	5	98	4	None	None	79.30
5B	459	75	0[5]	75	5	98	4	6-hr. soaking[6]	Wet sand[7]	99.00

[1] Number of days on which temperature dropped to 32° F. or below.
[2] Laboratory temperature averaged 75° F.
[3] On first day in laboratory.
[4] Three dippings 3 weeks apart, beginning after 51 days dry in laboratory.
[5] Contact moisture applied immediately after cocoons were brought into laboratory.
[6] Immersion.
[7] Water-saturated environment.

The above data demonstrate that *Harrisina brillians* is able to survive in varying degrees when exposed during diapause to extremes of cold and aridity. This is to be expected of a desert insect. Both cold and moisture, within limits, are aids to survival.

On the basis of these studies it may be concluded that *Harrisina brillians* is well adapted to climatic conditions in southern California and might develop even more successfully north of its present location. Periods of extreme desiccation during hibernation, when weather is warm, markedly cut down on skeletonizer populations. In contrast, such conditions are not injurious during the summer months except perhaps indirectly as they affect food quality. Other things being equal, heaviest survival may be expected after a season in which rains occur in the fall. The quantity of precipitation during the winter, even in dry years, is quite enough for heavy survival.

The relation of aridity and temperature to survival of *Apanteles* sp. "A" during diapause is shown in table 4. The cold-rest exposures were the same as those already given for corresponding lots of pupae of *Harrisina brillians*. It is evident from a comparison of these data with those of table 1 and 2 that *Apanteles* sp. "A" is even more sensitive to moisture deficiency than is its host. The paired experiments 5A and B and 14A and B demonstrate the importance of moisture to survival of *Apanteles* sp. "A" in the laboratory and during the emergence period. Except in Lot 13, survival appears to be directly correlated with extremes of cold intensity and duration. The reason for this inconsistency is not known. At any rate the greatest survival occurred at the lowest temperatures employed. *Apanteles* sp. "A" readily withstood 3 weeks of constant freezing temperature. Even-broodedness with *Apanteles* sp. "A," as with its host, is in direct correlation with contact moisture during diapause. From these results it appears that *Apanteles* sp. "A" would probably be able to adapt itself to almost any ecological niche that its host might occupy, although it might be less effective in an area of extreme aridity.

Few facts are available regarding the relation of climatic factors to winter survival of *Sturmia harrisinae*. This is because no reliable method was discovered to determine the presence of the overwintering parasite until shortly before or at the time of emergence of the fly; therefore, accurate counts could not be made. Laboratory emergence records show, however, that the highest percentages of parasitism of its host occurred in Lots 1 and 5 (A and B combined). These records indicate that this tachinid fly is able to survive when subjected to extremes of aridity (1) and cold (5). Like *Apanteles* sp. "A," it is well adapted to Arizona desert conditions, and field observations to date indicate that it will also prove to be adapted to conditions in southern California.

SUMMARY.—Requisite to a year-round study and propagation of the parasites of the western grape leaf skeletonizer, *Harrisina brillians* B. & McD., encountered during two years of exploration, was an investigation of diapause in this bi- or trivoltine host insect. In the course of this investigation, data were acquired

on the relation of climatic factors to winter mortality of *H. brillians* and two of its parasites, *Apanteles* sp. "A" and *Sturmia harrisinae* Coq.

Diapause was induced in *Harrisina brillians* by photoperiod during the larval stadia. After the inception of diapause, the photoperiodic effect was not overcome in less than 120 days, irrespective of external conditions. By using artificial light of minimum intensity of 10 foot-candles to augment daylight, so that the ratio of hours of light to darkness was maintained at 15:9, diapause was prevented in almost all of the host insects, and continuous generations were reared throughout the year. The "diapause" of the parasites was not completely clarified.

Winter mortality of both *Harrisina* and *Apanteles* sp. "A" was correlated with aridity and high temperature during diapause. With both species contact moisture was required to produce heavy survival and was directly correlated with even-broodedness. These species and *Sturmia* readily withstood temperatures as low as 32° F. on 98 days of cold rest, and an extreme of 5° F.

The survival of these species under the extremes of temperature and aridity employed in this study leaves little doubt that *Harrisina brillians* and its parasites *Apanteles* sp. "A" and *Sturmia harrisinae* can successfully adapt themselves to climatic conditions almost anywhere that grapes are grown in California.

LITERATURE CITED

Andrewartha, H. G. 1952. Diapause in relation to the ecology of insects. Cambridge Philos. Soc. Biol. Rev. **27:** 50–107.

Babcock, K. W. 1924. Environmental studies on the European corn borer (*Pyrausta nubilalis* Hbn.). JOUR. ECON. ENT. **17:** 120–5.

Babcock, K. W. 1927. The European corn borer *Pyrausta nubilalis* Hubn. I. A discussion of its dormant period. Ecology **8:** 45–59.

Dickson, R. C. 1949. Factors governing the induction of diapause in the oriental fruit moth. Ann. Ent. Soc. Amer. **42:** 511–37.

Ditman, L. P., G. S. Weiland, and J. H. Guill, Jr. 1940. The metabolism in the corn earworm. III. Weight, water, and diapause. JOUR. ECON. ENT. **33:** 282—95.

Flemion, F., and A. Hartzell. 1936. Effect of low temperature in shortening the hibernation period of the egg stage. Contrib. Boyce Thompson Inst. **8:** 167–73.

Kogure, M. 1933. The influence of light and temperature on certain characters of the silkworm. Kyushu Imp. Univ. Dep. Agric. Jour. **4:** 1–93.

Komarova, O. S. 1949. Causes that bring about the diapause of the grapevine leafroller (*Polychrosis botrana* Schiff). (In Russian.) Dokl. Akad. Nauk USSR. (N.S.) **68**(4): 781–4, Moscow. (Abs. Rev. Appl. Ent., Ser. A **40:** 57.)

Pepper, J. H. 1937. Breaking the dormancy in the sugar-beet webworm, *L. sticticalis* L., by means of chemicals. JOUR. ECON. ENT. **30:** 380.

Prebble, M. L. 1941. The diapause and related phenomena in *Gilpinia polytoma* (Hartig). I. Factors influencing the inception of diapause. Canad. Jour. Res., Sect. D, **19:** 295–322.

Rice, P. L. 1937. Effect of moisture on emergence of the ragweed borer, *Epiblema strenuana* Walker, and its parasites. JOUR. ECON. ENT. **30:** 108–15.

Roubaud, E. 1922. Études sur le sommiel d'hiver Pré-imaginal des muscids. Bul. Biol. de la France et Belg. **56:** 455–544.

Squire, F. A. 1937. A theory of diapause in *Platyedra gossypiella* Saund. Trop. Agr. **14:** 299–301 (Abs. Rev. Appl. Ent., Ser. A. **26:** 83–4).

Squire, F. A. 1939–40. Observations on the larval diapause of the pink bollworm, *Platyedra gossypiella* Saund. Bul. Ent. Res. **30:** 475–81.

Townsend, M. T. 1926. The breaking-up of hibernation in the codling moth larva. Ann. Ent. Soc. Amer. **19:** 429–39.

Host Relationship Studies of *Lygus* in South Central Washington[1]

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Lygus bugs have been long known as important destructive pests of a multitude of host plants. Sorenson (1932) was among the first to show that *Lygus* injury to alfalfa flowers results in a variable amount of flowerfall; later (1939) he confirmed his earlier observations and showed that blasting of alfalfa buds and shriveling of seeds were caused by *Lygus* feeding. Carlson and others (1950) found that alfalfa plots where lygus bugs were controlled yielded nearly eight times as much seed as plots in which the bugs were not controlled. Stitt (1944) showed that *Lygus hesperus* Knight caused the greatest percentage of brown (non-viable) seeds and was most responsible for the failure of pods to set; that *L. oblineatus* (Say) caused an intermediate amount of damage; and that *L. elisus* Van Duzee caused the least damage. Lygus bugs are polyphagous, and Stitt (1940) as well as other investigators have compiled extensive lists of host plants. Since there is differential damage by the various species, and because of the large acreages of alfalfa and other leguminous crops grown for seed in the Lower Yakima Valley, and because of the likelihood that a considerable acreage of legume seed crops will be grown in the Columbia Basin Project, the following study was undertaken.

METHODS.—Eight representative alfalfa fields were chosen for periodic checking from June 15 to August 31, 1950. Fields numbered 1 through 4 were located in the Lower Yakima Valley in the Sunnyside-Grandview-Prosser area. Field No. 5 was in a recently opened irrigation area, the Pasco Pump Unit of the Columbia Basin Project. This was the second year of irrigation in this area, and little information was available about insects affecting legume seed production there. Fields numbered 6 through 8 were located in the Columbia Basin in the Quincy-Moses Lake region. This likewise is a newly irrigated area and much of the land surrounding the fields is in sagebrush. All fields were planted to the Ranger variety, except Field No. 7 which was planted to Buffalo.

Samples were collected with a 15-inch insect net from each field every 2 weeks. Four samples of 25 sweeps were made at various points throughout the field at the time of checking. The insects so collected were immediately killed with potassium cyanide. Samples taken on host plants, other than in alfalfa fields, consisted of 50 sweeps with the 15-inch insect net. Because of the number of such samples taken, only a representative number of these samples is included in this paper.

Preliminary studies were undertaken in 1950 to determine *Lygus* preference, if any, for various varieties of alfalfa. Five varieties (Buffalo, Ranger, South Dakota, Ladak, and Turkistan) were planted in a Latin Square at the Irrigation Experiment Station, Prosser, Washington. Three of these replications were sampled on August 31, 1950, 50 sweeps of the net constituting the sample from each 20′×20′ plot. The entire five replications were sampled on August 23, 1951, for *Lygus* in the same manner as in 1950. In addition, 16 varieties being tested at the experiment station for adaptability to this area were sampled in 1951 to ascertain *Lygus* preference. The four replicates of the randomized block design were checked on September 4 by taking a 25-sweep sample from each plot. Counts from both of these experiments were transformed to the square root of the count prior to statistical analysis.

RESULTS AND DISCUSSION.—All fields except No. 6 were treated with insecticides for lygus bug control during the course of this study. Consequently, they yielded little information concerning the seasonal cycle of the bug, but were useful in determining species differences. Since Field No. 6, which was located 2 miles west of Quincy, Washington, received no insecticides whatever, it may be used as an indicator of the seasonal cycle of the lygus bug as found in South Central Washington.

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Table 1.—Total collections of *Lygus* for each of eight fields of seed alfalfa in Washington, 1950.

Field No.	Lygus				Total
	Elisus	*Hesperus*	*Desertus*	*Nigro-signatus*	
1	65	24	2	1	92
2	161	89	21	0	271
3	31	20	6	2	59
4	273	70	12	1	356
5	45	23	2	0	70
6	988	271	844	0	2103
7	745	202	49	0	996
8	256	50	19	1	326
Total	2564	749	955	5	4273

On June 29 the first survey of this field was taken. At this time there were 3.20 adult and 0.47 nymphal lygus bugs per sweep. On July 13 the adult population was only 0.80 bugs per sweep, whereas the nymphal population was 5.28 per sweep. By July 27 the high nymphal population of July 13 was reflected in the increased adult population to 9.02 bugs per sweep, and the nymphal population had risen to 7.25 bugs per sweep. At the August 9 sampling, both adult (6.64 per sweep) and nymphal (2.28 per sweep) populations had declined from the previous survey's peak. However, the adults decreased in number more slowly than the nymphs. The adult population on August 23 dropped to 1.37 bugs per sweep, but there was a tremendous build-up of nymphs to 11.74 per sweep.

It is extremely doubtful that the large decrease in adult populations between June 29 and July 13 resulted from natural mortality of overwintering individuals. The population of adults on the earlier date appears to be too high to have consisted of only overwintering forms. In view of the earliness of *Lygus* activity in the spring, it was very late in the season for them to be occurring in such numbers. Therefore, this adult population probably represents the adults of a first generation. As the adults began to decline, there was a steady increase in nymphal numbers as the eggs of this first generation hatched. This nymphal population reached a peak

Table 2.—*Lygus* populations from various plants in alfalfa growing areas, south central Washington, 1950. Fifty sweeps per sample.

Locality	Host Plant	Adults				Total Nymphs	Total Lygus
		Elisus	*Hesperus*	*Desertus*	*Nigro-signatus*		
Prosser	*Salsola Kali*	90	0	24	0	443	557
Quincy	*Salsola Kali*	157	0	118	0	104	379
Prosser	*Salsola Kali*	233	4	38	1	51	327
Burke	*Salsola Kali*	58	3	109	0	19	189
Mabton	*Salsola Kali*	181	7	0	0	134	322
Moses Lake	*Salsola Kali*	92	4	2	0	98	129
Prosser	*Bassia hyssopifolia*	225	7	0	0	182	414
Prosser	*Bassia hyssopifolia*	312	61	0	1	306	680
Grandview	*Erigeron canadensis*	7	172	11	0	26	216
Prosser	*Melilotus* spp.	15	8	0	0	1	24
Grandview	*Melilotus* spp.	5	15	0	0	0	20
Prosser	*Melilotus* spp.	30	88	1	0	27	146
Prosser	*Brassica* spp.	29	17	0	0	0	46
Ellensburg	*Brassica* spp.	0	1	1	0	1	3
Pullman	*Brassica* spp.	0	9	0	0	25	34
Prosser	*Urtica holosericea*	177	14	0	0	15	206
Grandview	*Chenopodium album*	5	0	0	0	0	5
Grandview	*Chenopodium album*	72	0	0	0	0	72
Wapato	Alfalfa (Hay)	13	71	0	0	0	84
Prosser	Alfalfa (Cover crop)	43	62	1	0	3	109
Ellensburg	Alfalfa (Hay)	14	16	0	0	0	30
Prosser	Alfalfa (Cover crop)	18	88	0	0	184	290
Prosser	Peppermint	8	5	0	1	2	16
Mabton	Peppermint	41	31	0	0	159	231
Prosser	Peppermint	26	11	0	1	178	216
Prosser	Beans	24	8	0	0	1	33
Prosser	Beans	24	1	2	0	9	36
Prosser	Potatoes	20	19	0	0	0	39
Prosser	Potatoes	1	4	0	0	8	13
Quincy	Potatoes	8	1	0	0	0	9
Moses Lake	Sugar beets	5	0	0	0	0	5
Prosser	Sugar beets	36	8	0	0	2	46

Table 3.—*Lygus* populations on five alfalfa varieties, Prosser, Washington. Fifty sweeps per sample.

	1950	1951	
VARIETY	Mean Number per Plot[1]	Mean from Transformed Data[2]	Calculated Mean Number[2]
Ladak	1148	19.58	383
South Dakota 12	1265	30.72	944
Turkistan 19300	960	25.14	632
Buffalo	1479	30.69	942
Ranger	1337	35.87	1287
		S.E. $\bar{x}=1.64$	

[1] These figures are based on 3 replications only and have *not* been transformed.
[2] Based on all 5 replications.

Table 4.—*Lygus* populations on sixteen alfalfa varieties, Prosser, Washington, 1951. Twenty-five sweeps per sample.

VARIETY	MEAN FROM TRANSFORMED DATA	CALCULATED MEAN NUMBER
Hardistan	11.54	133
Nemastan	12.72	162
Turkistan 19300	12.73	162
Grimm	14.13	200
Williamsburg	14.52	211
Ladak	14.54	211
Buffalo	15.23	232
Talent	15.59	243
Ranger (Mont.)	15.95	254
Atlantic	16.11	260
Narragansett	16.12	260
Rhizoma	17.43	304
South Dakota 12	18.13	329
Ranger (Neb.)	20.26	410
Wisconsin Syn. C.	20.68	428
Ranger (Ariz.)	21.53	464
	S.E. $\bar{x}=1.86$	

at the July 27 survey and then declined rapidly as these nymphs became adults. The adult population dropped off slowly at first, but by August 23 most of its members had oviposited and died. By August 23 many of the progeny of the second generation were hatched and feeding. Since this is still relatively early in the season, it seems reasonable to suppose that these nymphs could mature and thus produce the third complete generation. Therefore, it appears that there are at least three complete generations of *Lygus* in the Columbia Basin and possibly a partial fourth. This hypothesis is borne out by the fragmentary evidence obtained from the fields treated for *Lygus* control.

Populations of *Lygus elisus*, *L. hesperus*, and *L. desertus* Knight, when considered for all fields throughout the season, group themselves into approximately a 34:10:13 ratio, respectively, with a very few *L. nigrosignatus* Knight occurring (Table 1). These four species were the only ones found in alfalfa seed fields during this survey, although one specimen of *L. oblineatus* was captured on alfalfa during the varietal trials. If the total population figures are broken down to species for the Yakima Valley and for the Columbia Basin, the ratio of *L. elisus* to *L. hesperus* to *L. desertus* is about 129:50:10 in the valley, while in the basin the ratio for the three species is 37:10:17. Table 1 indicates that if it were not for Field No. 6 (untreated with insecticides) the proportion of *L. desertus* would be much lower in the basin—149:39:10—approaching the ratio as found in the older irrigated area. Also the only field in which numbers of *L. desertus* rivaled numbers of *L. elisus* or exceeded numbers of *L. hesperus* was Field No. 6. In other fields in the basin the ratio of the three species was fairly close to that found in the valley. It seems possible that *L. desertus* is more susceptible to insecticides than the other species and is therefore more effectively controlled. Data from sweepings of other host plants where no control was used frequently show higher proportions of *L. desertus* than have been found on these seed fields.

A summary of the more pertinent data gathered from the survey of wild and cultivated plants growing in the seed producing areas is presented in table 2. Several weed plants, especially Russian thistle (*Salsola Kali*); smotherweed (*Bassia hyssopifolia*); horseweed (*Erigeron canadensis*); sweet clover (*Melilotus* spp.); wild mustard (*Brassica* spp.); nettle (*Urtica holosericea*) appear to be important reservoir hosts of *Lygus* spp. in South Central Washington. Only adults of *Lygus elisus* were found on *Chenopodium album*. The large numbers of nymphs of all instars found feeding upon alfalfa as an orchard cover crop or for hay, and on mint, indicated that they are important reservoir hosts. The data indicated that *Lygus* also breed quite extensively in this area on beans, potatoes, and beets. An occasional bug was found on

several other crop plants and weeds from time to time.

The single collection of lygus bugs from alfalfa variety plots in 1950 indicated that there might be statistically significant differences in bug populations between the several varieties if the study were carried out on a sufficient number of replications. In this preliminary work, Turkistan and Ladak harbored the lowest population while Ranger and Buffalo had the highest (Table 3). Although analysis showed these differences not to be significant, there were indications that further study might be profitable. Therefore, in the summer of 1951 all five plots in the Latin Square were sampled and the results analyzed. Table 3 shows that there were significant differences in the population densities of bugs on the different host varieties.

When the *Lygus* samples from the 16 alfalfa varieties were counted and analyzed, it was found that there were significant differences among the varieties beyond the 1 per cent level (Table 4).

The variety Ranger, which apparently is among the most susceptible to *Lygus* attack, is one of the most highly recommended varieties, on a basis of adaptability and yield, for production in these irrigated areas of Washington.

SUMMARY.—1. Of the five species of *Lygus* found in Central Washington during the course of this study—*L. oblineatus*, *L. nigrosignatus*, *L. elisus*, *L. hesperus*, and *L. desertus*—only the last three appear to be of economic importance to alfalfa seed production.

2. Although the over-all ratio of the three principal species of *Lygus*, *L. elisus; L. hesperus;* and *L. desertus*, from selected alfalfa seed fields in South Central Washington was approximately 34:10:13, the proportion of *L. desertus* was much higher in the field where no control measures were taken.

3. On the basis of the data from the fields in the Quincy-Moses Lake area of Washington, the author believes there to be at least three complete generations snd perhaps a partial fourth of lygus bugs per year.

4. Substantial nymphal and adult *Lygus* populations were found on several common weeds throughout the area studied, indicating that these weeds are important reservoir host plants. The most important appear to be: *Salsola Kali*, *Bassia hyssopifolia*, *Erigeron canadensis*, *Melilotus* spp., *Brassica* spp., and *Urtica holosericea*. Several other weeds as well as some cultivated crops evidently are suitable for *Lygus* to feed and breed upon in this area.

5. Lygus bugs exhibit a preference for certain varieties of alfalfa. Of the 16 varieties studied, the highest populations of lygus bugs were found on Ranger, Wisconsin Syn. C., and South Dakota; whereas the lowest populations occurred on Hardistan, Turkistan, and Nemastan.

LITERATURE CITED

Carlson, J. W. *et al.* 1950. Growing alfalfa for seed in Utah. Utah Agr. Expt. Sta. Circ. **125.**

Sorenson, C. J. 1932. The tarnished plant bug, *Lygus pratensis* (Linn.), and the superb plant bug, *Adelphocoris superbus* (Uhler), in relation to flower drop in alfalfa. Utah Acad. Sci. Proc. **9:** 67–70.

Sorenson, C. J. 1939. *Lygus hesperus* Knight and *Lygus elisus* Van Duzee in relation to alfalfa seed production. Utah Agr. Expt. Sta. Bul. **284.**

Stitt, L. L. 1940. Three species of the genus *Lygus* and their relation to alfalfa seed production in southern Arizona and California. U.S.D.A. Tech. Bul. **741.**

Stitt, L. L. 1944. Difference in damage by three species of *Lygus* to alfalfa seed production. JOUR. ECON. ENT. **37:** 709.

Cucumber Beetles Attacking Melons in Northern California

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Cucumber beetles are among our most important insect pests of melons. The two species involved are the western spotted cucumber beetle. *Diabrotica undecimpunctata* Mann. and the western striped cucumber beetle, *Acalymma trivittata* (Mann.). These insects occur wherever melons are grown and may attack plants seriously from the time they first appear above ground until the crop is harvested. If left unprotected, it is questionable if a single melon field would escape damage and some beyond a doubt would be completely destroyed by these pests.

All varieties of melons are not equally preferred. Honeydew melon appears to be particularly attractive, and is always in danger of being seriously infested and damaged.

Cucumber beetles may injure melons in any or all of the four following ways: adults (1) may feed upon the foliage or (2) may scar the fruit, stems and crown, while the larvae (3) feed upon the roots or (4) upon that portion of the melon in contact with the soil.

Defoliation by Adults.—The nature of adult feeding on foliage is shown in figure 1. Under severe conditions of infestation large plants may be defoliated. However, most damage resulting from leaf feeding occurs on small plants. Under some conditions seedling stands may be killed before they have an opportunity to become established. Large adult populations should always be eliminated before they have an opportunity to oviposit. Once eggs have been deposited around the base of the plants it becomes impossible to control the subsequent larval stages in the soil.

Scarring of Fruit by Adults.—Adults are responsible for serious injury to the melon fruit. Where the adult population is large, nearly all the fruit may be damaged. The adults of both species prefer to feed on the young developing melons. After the skin hardens melons are much less subject to attack and a larger adult population can be tolerated at this time than during the period when there are quantities of small melons. It is always wise to keep melon fields under close observation and be in a position to treat them as soon as there is the first indication of adult feeding on melons.

Adult cucumber beetles tend to avoid the heat, and as a result their feeding on young melons is very likely to be mainly confined to the under side. Therefore, in making surveys the young melons should be turned over when searching for injury.

As stated previously, honeydew melons are particularly subject to serious damage. On very young melons that are still pubescent the injury appears as an etching of the surface (Fig. 2). On slightly older melons the feeding is deeper and somewhat more pronounced (Fig. 3). As the melons mature a considerable amount of scar tissue is formed. This tissue is mostly dark, scabby in appearance, and somewhat raised as shown in figure 4. As the melons reach maturity, the scabbed areas are distinctly raised and nearly white in color (Fig. 5). Where control measures are delayed, much of the young fruit may be injured as shown in figure 6.

The injury on other varieties of melons is whitish and scabby. The damaged area may be slightly depressed, sunken or deformed. Fig. 7 shows typical injury to crenshaw melon. Adults also scar the stems and crowns of the plants as shown in figure 10.

Scarring of Fruit by Larvae.—Where large larval populations have been allowed to develop, serious injury to melons frequently occurs. In some honeydew fields as many as 50 per cent of the melons have shown evidence of larval feeding. Melons resting on moist soil and in the later stages of development appear to be most subject to attack. The larvae bore into the fruit leaving dark, sometimes rather deep scarred areas. The wounds tend to cork over but at best present an unsightly appearance. A honeydew melon that has been injured by larval feeding is shown in figure 8.

Feeding on Roots by Larvae.—Melon plants are frequently injured by larvae feeding on their roots. It is believed that the western striped cucumber beetle is more destructive in this regard than is the western spotted cucumber beetle. Larvae sometimes kill young plants, and on occasions are responsible for the death

FIG. 1.—A honeydew melon leaf which has been injured seriously by the feeding of adult cucumber beetles.

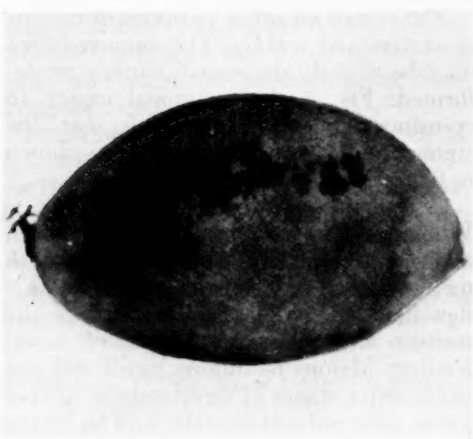

FIG. 2.—Adult cucumber beetle injury to young honeydew melon. Two-thirds natural size.

of old ones. Further, it is possible that larval feeding may furnish portals of entry for the fungus disease, verticillium wilt. In figure 9 is shown the root system of a honeydew melon that has been seriously fed on by cucumber beetle larvae. Some larval feeding is to be seen on the lower portion of the root in figure 10, but the scarring about the crown of the plant is typical of that caused by adults.

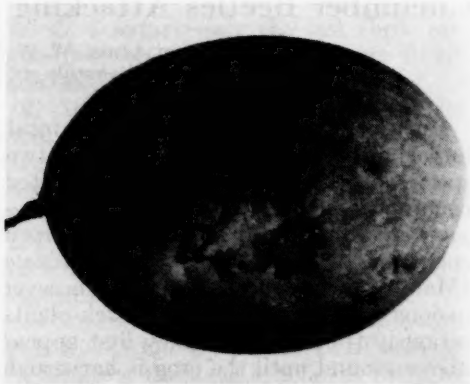

FIG. 3.—Adult cucumber beetle injury to young but slightly older honeydew melon than shown in figure 2. Two-thirds natural size.

FIG. 4.—Adult cucumber beetle injury as it appears on a maturing honeydew melon. Two-fifths natural size.

SOURCES OF INFESTATION.—Serious infestations of cucumber beetles arise from their breeding within a field or through migrations. There is no question but that destructive populations frequently develop within melon fields. This is attested to by the fact that destructive larval populations are often encountered and examinations of the soil about plants reveal many pupae and newly transformed adults.

Migrating beetles offer a continual problem. Frequently, during a very short period, melon fields are invaded by flights of adults of considerable magnitude. The source of these beetles is from other crops that are being harvested or from fields where harvest has been completed and which are drying up or are being disked or plowed under. Large movements may occur from alfalfa fields that are being cut for hay. Also in the case of the western spotted cucumber beetle, sizeable migra-

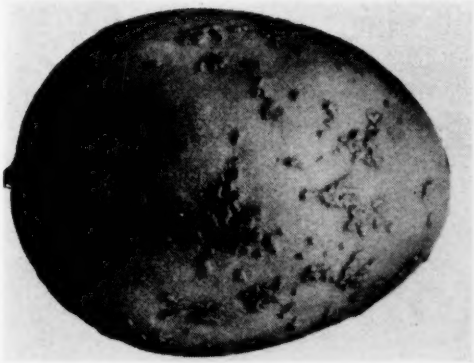

FIG. 5.—Characteristic adult cucumber beetle injury as it appears on a mature honeydew melon. One-fourth natural size.

tions in the spring may occur from uncultivated regions where the first spring generation tends to develop.

Cucumber beetles like moisture and melon fields are particularly attractive to them during and just following irrigation. This response is most pronounced during periods of hot weather.

Although serious migrations may occur to melons of any variety, honeydew seems to be preferred. The crenshaw variety is very attractive as is also the casaba. Those melons that are covered with a netting such as the Persian variety appear to be the least attractive.

CONTROL.—Although cucumber beetles have a number of natural enemies, these agencies rarely are sufficiently effective to reduce the population to a level where control with insecticides is not required. Chemical control of the pest would be rather simple were it not for the fact that applications of some of the most effective materials such as DDT are likely to result in an increase in the spider mite or melon aphid population. Therefore it is desirable to obtain economic control with the fewest applications and lowest dosage possible. This is true because investigations have shown that where DDT is used in the melon insect control program, serious increases in the melon aphid or spider mite populations are associated with heavier dosages and frequency of applications. (Michelbacher & Middlekauff 1950, Michelbacher *et al.* 1952)

FIG. 7.—Adult cucumber beetle injury to crenshaw melon. About one-third natural size.

FIG. 6.—Severe adult cucumber beetle injury to young honeydew melon where control measures were delayed. Two-fifths natural size.

FIG. 8.—Cucumber beetle injury to honeydew melon. The light colored corky tissue is the result of adult feeding while the dark pitted areas in the center are caused by the larvae. About one-third natural size.

FIG. 9.—Root system of a honeydew melon plant that has been seriously fed upon by larvae of cucumber beetles.

FIG. 10.—Honeydew melon. Scarring about crown due to feeding by adults and injury on lower part of root caused by larval feeding.

Although not nearly as effective as DDT, a cryolite dust is frequently recommended during the early stages of growth in order to avoid the adverse effects caused by too much DDT. A 40 to 50 per cent cryolite dust, applied by ground equipment, will give satisfactory control if only the beetles are present. However, if thrips are abundant or if the melon leafhopper, *Empoasca abrupta* DeLong is threatening, the young plants should be lightly but evenly treated with a 3 per cent DDT dust. Control of cucumber beetles has also been obtained on seedling stands by applying undiluted calcium arsenate of low soluble arsenic content with a fertilizer attachment at time of cultivation. The calcium arsenate is allowed to dribble out over the rows.

Investigations have shown that where vine growth has completely covered the rows, a 3 per cent DDT dust, at 30 pounds per acre, or its equivalent as a spray is sufficient to give adequate control of cucumber beetles as well as other pests of melons against which DDT is effective. Honeydew is one of the few melons that is not injured by sulfur. Therefore where DDT is used on this variety it should, where feasible, be used in combination with 50 per cent sulfur. Serious infestations of spider mites seldom develop where this mixture is applied before spider mites become evident.

Where DDT is used on other varieties and a serious spider mite infestation is suspected it can be used in combination with 3 per cent aramite, or with 7.5 per cent ovotran. If at all possible, either of these mixtures should be applied before destructive spider mite populations have developed. Where DDT is applied as a spray, aramite can be incorporated with it at the rate of at least one pound of actual material per acre to forestall a serious spider mite infestation. Where the spider mite population is held well in check there is no need of adding an acaricide to all DDT treatments. It is possible to produce a crop where DDT is used without adding an acaricide, and in most cases not more than a single application of a mixture should be needed if the treatment is timely and thoroughly applied.

A 2 per cent parathion dust at 30 pounds per acre is effective against cucumber beetles, and has been used successfully in controlling the pest during the entire growth of a crop. Single applications have remained effective for periods upwards to three weeks. Control of the beetles has also been obtained where a stable one per cent tetraethyl pyrophosphate dust has been applied at the rate of

30 pounds per acre. A 5 per cent malathon dust at 25 pounds per acre has also shown promise.

Dieldrin at 0.5 pound, or aldrin at 1 pound, or heptachlor at 1 pound per acre have all resulted in excellent control of cucumber beetles. None of these three insecticides has as yet been released for use on melons. A residue problem is not anticipated and extensive taste tests conducted with dieldrin treated melons have indicated no off flavor. These insecticides are toxic to bees and even where used on experimental plots treatments should be applied at night or in early morning before the bloom opens. No evidence of serious injury to bees has been observed where these insecticides have been applied before the bloom opens. However, the treated areas have seldom been more than 25 acres, and it is difficult to predict whether this would still be the case if numerous fields in the same area were treated. Michelbacher *et al.* (1952) found that all of these materials have a tendency to increase the spider mite population. If dieldrin, aldrin, or heptachlor are released for use on melons, best results will probably be obtained where they are combined with an effective acaricide. Of the three insecticides, dieldrin has been used most extensively in the present investigations, and it appears to be more effective than the other two. With the exception of the melon leafhopper and spider mites, it has given good control of the other principal pests of melons.

In order to protect bees after the plants have come into bloom, applications of all recommended insecticides that are injurious to them should be made during the time of the day when the flowers are closed.

TIMING OF TREATMENTS.—Treatments, particularly during the early stages of growth and melon formation, should be applied as soon as cucumber beetles become noticeable. The best time to search for them is in the morning shortly after it begins to warm up. They are quiet when it is cold or when it is hot, which makes it difficult to estimate the size of the population when either of these conditions exist. They are active and are easily disturbed when it is moderately warm, and the relative number of beetles can be rather easily estimated by walking through a field. Adult populations are likely to be very uneven and it is not uncommon to find a portion of a field heavily infested while the population in the rest of the field may be below an economic level. Where fields are large it may be necessary to treat only that portion which is severely infested. Because large populations cannot be tolerated, it is often necessary to treat melon fields when cucumber beetles are the only pest present in sufficient numbers to justify the treatment. However, if at all possible it is well to time treatments so that several pests may be controlled at the same time.

On preferred melons such as honeydew usually 3 to 4 applications of DDT or other effective insecticides are needed to give adequate protection during the growth of a crop.

SUMMARY.—The western spotted cucumber beetle, *Diabrotica undecimpunctata* Mann., and the western striped cucumber beetle, *Acalymma trivittata* (Mann.), are serious pests of melons. They injure melons in any or all of the four following ways: (1) adults feed upon the foliage or (2) scar the fruit, stems and crowns, while the larvae (3) feed upon the roots or (4) scar melons by feeding upon that portion of the fruit in contact with the soil.

Sources of serious infestations arise from breeding within melon fields or from migrations from other crops that are being harvested or have been harvested and are drying out or being disked under. Also, in the case of the western spotted cucumber beetle, migrations of considerable magnitude may occur in the spring from uncultivated regions where the first spring generation generally develops. Honeydew melons are among the preferred hosts, and are more subject to serious injury than are most other varieties of melons.

It is necessary that control measures be applied as soon as an adult cucumber beetle population becomes noticeable. Control would be rather simple were it not for the fact that some of the most effective materials such as DDT are likely to result in an increase in the spider mite or melon aphid population. Because of this it is desirable to obtain economic control with the fewest applications and the lowest dosage possible. Not more than one pound of actual DDT per acre is needed to give effective control of cucumber beetles and the other melon in-

sects against which DDT is effective. On honeydew melons DDT can be used in combination with 50 per cent sulfur to prevent a serious infestation of spider mites. On other varieties, or even with honeydews, DDT can be used in combination with aramite or ovotran if a serious spider mite population is anticipated.

Successful control of cucumber beetles can be obtained with a 2 per cent parathion dust applied at 30 pounds per acre. Tetraethyl pyrophosphate applied as a one per cent dust at the rate of 30 pounds per acre has also shown promise as has a 5 per cent malathon dust at 25 pounds per acre.

Dieldrin, aldrin, and heptachlor are all effective in controlling cucumber beetles, but to the present time they have not been released for use on this crop. Of the three, dieldrin has shown the most promise for use in the melon insect control program.

In order to protect bees after plants have come into bloom applications of all insecticides that are injurious to them should be made at night or early in the morning before the flowers open.

ACKNOWLEDGMENTS.—The authors wish to express their appreciation to the several chemical concerns which contributed insecticides, help and equipment, and to B. Harlan and T. Dumars, Woodland and Herman Wood, Patterson who generously provided melon fields and other help. Thanks are due to the following for field and laboratory assistance: N. B. Akesson, Department of Agricultural Engineering, University of California, Davis; William H. Wade and C. S. Davis, research assistants, Department of Entomology and Parasitology, University of California, Berkeley and E. E. Stevenson, Farm Advisor Stanislaus County.

LITERATURE CITED

Michelbacher, A. E. and W. W. Middlekauff. 1950. Control of the melon aphid in Northern California. JOUR. ECON. ENT. **43**(4): 444–74.

Michelbacher, A. E. and W. W. Middlekauff. 1952. Mites on melons in Northern California. JOUR. ECON. ENT. **45**(3): 365–70.

Michelbacher, A. E., W. W. Middlekauff, O. G. Bacon, and L. C. Glover. 1952. Aldrin, dieldrin, and heptachlor to control California melon insects. JOUR. ECON. ENT. **45**(3): 470–5.

Distribution and Control of Forbes Scale in the Midwest[1]

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The Forbes scale, *Aspidiotus forbesi* Johns, has been known in the Midwest since 1894. It was first mentioned in literature in 1896, when Johnson (1896a) gave the species its name. More complete information was published later in the same year (Johnson 1896b and c). He indicated a belief that this scale would rival the San Jose scale in destructiveness.

Although originally reported on a wide variety of fruit trees, the Forbes scale was thought to be primarily a pest of cherry. In spite of Johnson's opinion of its probable destructiveness, it was not, prior to 1945, generally considered of economic importance as a pest of apple and peach. In contrast, its near relative the San Jose scale, *Aspidiotus perniciosus* Comst. has been generally distributed through the Midwest for nearly a half century, and from time to time severe infestations have developed on apple and peach trees where effective control measures have not been applied. For example, in 1922 this scale killed mature apple trees on more than 1000 acres of orchard in southern Illinois alone (Flint 1923).

Beginning about 1946, the comparative abundance of the different species of scale insects present in midwestern orchards began to change, and by 1948 a definite trend was evident. Infestations of Forbes scale were increasing, whereas the San Jose scale and oystershell scale, *Lepidosaphes ulmi* (L.), were becoming less abundant.

DISTRIBUTION.—During March and April 1951 a survey was made to evaluate the status of scale insects in orchards in the Midwest. The area surveyed extended from the northern boundary of Indiana in a zigzag line southward through Indiana, southern Illinois, western Kentucky, and western Tennessee—approximately 475

[1] Presented at the meeting of the American Association of Economic Entomologists at Philadelphia, Pa., December 15 to 18, 1952.

miles north and south and 200 miles east and west, between latitudes 41° 7′ and 35° 6′ and longitudes 85° 35′ and 88° 80′. The survey included 36 apple orchards selected at random without reference to spray programs used or type of orchard. Thirty-three peach orchards were paired with an equal number of apple orchards, wherever possible on the same property. In Indiana 7 cherry and 6 plum orchards were also surveyed.

Representative samples of scale from all orchards infested were collected and submitted to the Bureau's Division of Insect Identification for identification.

Forbes scale was found in 72 per cent and San Jose scale in 19 per cent of the apple orchards. Putnam scale, *Aspidiotus ancylus* (Putn.), was found in one apple orchard near Fulton, Kentucky. Scurfy scale *Chionaspis furfura* (Fitch), was found in two apple orchards in north-central Indiana between latitudes 40° 2′ and 40° 8′. *Lecanium* sp. was found on both apple and peach, but only an occasional specimen. Of interest is the fact that no oystershell scale was found on apple.

Of the peach orchards 42 per cent were infested with San Jose scale as compared with 3 per cent (one orchard) where Forbes scale was found. Walnut scale (*Aspidiotus juglans-regiae* Comst.) was present in an orchard near Villa Ridge, Illinois, where its presence had been previously noted by Chandler (1950).

Six plum orchards in southern Indiana had three infested with Forbes scale, two with San Jose scale, and one with oystershell scale.

Seven cherry orchards showed three infested with Forbes scale. No other scale was found.

The survey showed that Forbes scale is now the predominant scale species on apples in the four midwestern States visited, and that most of the apple orchards had a scale problem. Scale infestations were severe in 22 per cent of the orchards, moderate in 31 per cent, light in 33 per cent, and 14 per cent had no scale. The degree of infestation seemed correlated primarily with the thoroughness of spray applications and pruning. The better cared-for orchards had the least injury. In all instances of severe scale infestation the species was Forbes. Scale was not so great a problem on peaches as on apples, although it was present in over one-third of the orchards surveyed, the predominant species being San Jose.

The limited survey indicated that Forbes scale is the predominant species of scale present in plum and cherry orchards in this area. The rapid build-up of Forbes scale in midwestern orchards and the decrease in injury by San Jose scale can be attributed to three principal factors. First, DDT, which has been in general use in this area since 1946, may have reduced the numbers of predators and parasites that formerly kept this scale at low levels. Second, as shown by O'Neill (1951), DDT used in two or more cover sprays controls San Jose scale. In the Midwest it can be assumed that annual sprays of DDT have reduced San Jose scale, but have apparently increased populations of Forbes scale. Third, Forbes scale thrives best in a mild climate. Mortality is often severe when the temperatures drop below −15° F. This was demonstrated in the Vincennes, Indiana, area during the winter of 1950–51, when temperatures ranged between −17° and −30°, and reduced infestations of Forbes scale below the general levels of the preceding few years. Winters from 1946 through 1950 had been relatively mild in the area surveyed.

CONTROL.—Steiner *et al.* (1948) showed that 25 per cent parathion used in two summer sprays at 1 pound, in three cover sprays at 0.5 pound, or in six cover sprays at 0.25 pound to 100 gallons gave almost perfect control of Forbes scale. They also reported that summer sprays of parathion reduced infestations better than 3 per cent dormant oils. McAlister *et al.* (1949) reported similar results. Investigations at the Vincennes laboratory in 1950 confirmed these earlier findings and also indicated that EPN might not be so effective as parathion. These early studies were conducted in orchards in which the infestation was scattered and varied widely from tree to tree. It is difficult to find orchards where Forbes scale infestations are uniform throughout the block. Likewise rates of build-up differ with the variety. For example, Turley and Winesap are susceptible to rapid scale build-up, whereas development on Rome is especially slow. However, heavy infestations may occur on any variety.

Discovery of an exceedingly heavy and

uniform infestation of Forbes scale in the Bolten orchard at Linton, Indiana, early in 1951 made it possible to conduct more extensive control studies during 1951 and 1952. The trees in this orchard were about 38 years old and extra large. Sprays were applied with a conventional high-pressure sprayer, delivering 35 gallons per minute, one operator being stationed in a tower and another on a low rear platform. All parts of the tree were thoroughly drenched.

No dormant treatments other than those used for experimental purposes were applied to these plots. During the growing season the grower applied the usual fungicides and insecticides to all plots except that he used no materials likely to affect Forbes scale. The materials applied by the grower included wettable sulfur, ferbam, lead arsenate, lime, DDT and Aramite. The scalecides were applied as separate treatments. Single-tree plots, replicated four times, twice on Winesap and generally once each on Red Delicious and Rome, were used. In 1951 the plots were randomized; in 1952 they were rearranged so that the irregular infestations caused by the 1951 experiments were leveled off between plots as much as possible.

Fruit infestations were estimated at harvest by examining a random sample of 250 apples per tree for each drop pick-up and picking. In 1951 the scale-control data obtained on the fruit were substantiated by twig counts taken in December from the tops of each tree, where Forbes scale is most prevalent. Ten 5-inch twigs from each tree were cut from nodes so that each included 2.5 inches of 1950 and 2.5 inches of 1951 growth. Thus 50 inches of twig were examined for each tree.

The materials used and control of Forbes scale obtained in 1951 are summarized in table 1. Metacide and parathion gave the greatest reductions. They were the most effective when applied in three cover sprays timed to coincide with the periods crawlers were generally active, which in general practice would be about the time the second, fifth, and sixth cover sprays were applied. Control might have been better had additional cover sprays been included, as it was difficult to cover thoroughly all parts of these old, gnarled trees, and the infestation was unusually severe.

While reducing the scale infestation somewhat, EPN did not maintain satisfactory control. Endrin had little, if any, effect on the scale present.

The dormant oils used were of the paraffinic type, and had the following specifications:

	522 Oil	*776 Oil*	*Commercial Oil*
Viscosity (seconds Saybolt at 100° F.)	96–104	105–115	90
Gravity (°API)	27–31	30–34	34.5
Viscosity index (ASTM)	67	93	96
Per cent unsulfonated residue (ASTM)	90	99	—
Pour point (° F.)	25	25	—

The 522 and 776 oils were emulsified with blood albumin. Differences in control obtained with the three oils were not significant. It is evident, however, that the dormant oils were less effective than parathion or Metacide applied in three summer sprays. The triethanolamine salt of dinitro-*sec*-butylphenol applied as a dormant spray was less effective than dormant oil sprays.

The control obtained with Metacide, parathion, and dormant oils in 1952, summarized in table 2, paralleled that in 1951. Four applications at 0.5 or 1 pound of 15 per cent parathion per 100 gallons, starting at the time first-brood crawlers became active, or two applications at 1.5 pounds 3 weeks apart while first-brood crawlers were active, gave better control than 1.5 pounds in two late-season covers.

Three new insecticides were included in the 1952 tests—malathon, Systox, and diethoxyphosphinothioyl ethylethylphosphonate.[2] A 50 per cent emulsible malathon in four summer applications at 1 pint to 100 gallons gave control that compared favorably with that obtained with the same concentration of 15 per cent parathion. A 48 per cent Systox in two early-summer sprays at 0.25 pint to 100 gallons did not reduce scale populations substantially. Diethoxyphosphinothioyl ethyl ethylphosphonate in a 25 per cent emulsible liquid at 1 pint to 100 gallons did not give such good control as 0.5 pound of 15 per cent parathion when used in four summer applications.

Three dormant oils heretofore untested for Forbes scale control were compared with 522 oil. Specifications of these oils were as follows:

[2] Supplied by the Virginia-Carolina Corporation.

	1519 Oil	1526 Oil	578 Oil
Viscosity (seconds Saybolt at 100° F.)	63.5	149.3	154.0
Gravity (°API)	30.3	29.5	24.9
Viscosity index (ASTM)	80	80	9
Per cent unsulfonated residue (ASTM)	89	78	92
Pour point (° F.)	20	10	5

The 1519 and 1526 oils had a high paraffinic base, whereas the 578 oil was a naphthenic type.

Table 1.—Control of Forbes scale, Bolten Orchard, Linton, Indiana, 1951.

Insecticide	Quantity per 100 Gallons	Apple Variety[1]	Per Cent of Fruit Infested	Number of Live Scales per 5-Inch Twig
Summer sprays (3 covers, May 22, July 18, and Aug. 15)				
Parathion 15% WP	0.5 lb.	Winesap	45.3	5.1
		Red Delicious	12.8	0.4
		Rome	10.2	1.4
		Average	22.8	2.3
	1 lb.	Winesap	24.7	0.1
		Red Delicious	3.0	1.6
		Rome	10.8	0.7
		Average	12.8	0.8
	1.5 lb.[2]	Winesap	40.5	6.8
		Red Delicious	25.1	35.3
		Average	32.8	21.0
Metacide 33% Em	0.5 pt.	Winesap	7.6	0.2
		Rome	7.7	1.3
		Average	7.6	0.7
	1.5 pt.[2]	Winesap	32.9	4.3
		Rome	42.9	3.2
		Average	37.9	3.7
EPN 25% WP	0.5 lb.	Winesap	94.4	18.9
		Red Delicious	79.9	13.3
		Rome	88.4	7.3
		Average	87.6	13.2
	1 lb.[2]	Winesap	96.8	53.4
		Red Delicious	52.6	24.4
		Rome	96.2	66.6
		Average	81.9	48.1
EPN 50% Em	0.25 pt.	Winesap	73.3	9.5
		Red Delicious	34.4	7.6
		Rome	72.0	8.3
		Average	59.9	8.5
Endrin 6% Em	2 qt.	Rome	93.3	39.9
Dormant sprays (1 application, Mar. 5)				
522 oil	3 gal.	Winesap	75.2	12.4
		Red Delicious	4.1	4.9
		Rome	18.5	3.2
		Average	32.6	6.8
	4 gal.	Winesap	66.0	10.0
		Red Delicious	8.6	20.2
		Rome	58.3	9.1
		Average	44.3	13.1
776 oil	2 gal.	Winesap	66.9	24.4
		Red Delicious	9.9	2.2
		Rome	33.3	8.9
		Average	36.7	11.8
	3 gal.	Winesap	54.9	6.9
		Red Delicious	27.0	12.8
		Rome	36.1	14.4
		Average	39.3	11.4
Commercial oil 96% Em	3.5 gal.	Winesap	38.4	7.0
		Red Delicious	5.8	1.5
		Rome	31.7	3.6
		Average	25.3	4.0
Triethanolamine salt of dinitro-*sec*-butylphenol 36%	2 qt.	Winesap	77.2	19.1
		Red Delicious	22.9	5.2
		Rome	51.0	7.2
		Average	50.4	10.5
No insecticide	—	Winesap	96.6	54.3
		Red Delicious	89.3	77.7
		Rome	90.5	17.3
		Average	92.2	49.8

[1] Average number of apples per tree: Winesap 5448, Red Delicious 1027, and Rome 4524.
[2] One cover, May 22.

Table 2.—Control of Forbes scale, Bolten Orchard, Linton, Indiana, 1952.

Insecticide	Quantity per 100 Gallons	Apple Variety[1]	Per Cent of Fruit Infested	Per Cent Change from 1951
Summer sprays (4 covers, June 5 and 27, July 30, and Aug. 26)				
Parathion 15% WP	0.5 lb.	Winesap	7.0	−92.0
		Red Delicious	7.2	−73.3
		Rome	3.0	−91.7
		Average	5.7	−85.7
	1 lb.	Winesap	2.8	−95.7
		Red Delicious	4.5	−54.5
		Rome	4.7	−85.9
		Average	4.0	−78.7
	1.5 lb. 2 early covers only	Winesap	4.6	−92.4
		Red Delicious	3.2	−21.9
		Rome	0.8	−95.7
		Average	2.5	−70.0
	2 late covers only	Winesap	12.2	−74.0
		Red Delicious	11.2	+30.2
		Average	11.7	−21.9
DD 25% + parathion 3% WP on tobacco stems	2.5 lb.	Winesap	10.3	−61.8
		Red Delicious	0.4	−96.1
		Rome	0.6	−95.3
		Average	3.8	−84.4
DDT 25% + parathion 3% WP	2.5 lb.	Winesap	6.9	−89.1
		Rome	2.5	−67.5
		Average	4.7	−78.3
Metacide 50% Em	0.25 pt.	Winesap	6.0	−88.5
		Red Delicious	9.2	+58.6
		Rome	3.5	−89.0
		Average	6.2	−39.6
Malathon 50% Em	1 pt.	Winesap	1.8	−75.9
		Red Delicious	4.0	−78.8
		Average	2.9	−77.3
Diethoxyphosphinothioyl ethyl ethylphosphonate 25% Em	1 pt.	Winesap	55.5	−12.9
		Red Delicious	14.8	+393.3
		Rome	7.1	−34.3
		Average	15.8	+115.4
Systox 48.1% Em	0.25 pt. 2 early covers only	Winesap	77.7	+17.3
		Rome	76.3	−18.1
		Average	77.0	−0.4
Dormant sprays (1 application, Mar. 12)				
1519 oil	3 gal.	Winesap	67.8	−18.3
		Red Delicious	61.5	−31.1
		Rome	19.6	−78.3
		Average	49.6	−40.9
522 oil	3 gal.	Winesap	43.9	−17.2
		Red Delicious	35.9	+56.8
		Rome	27.8	−45.5
		Average	35.9	−2.0
1526 oil	3 gal.	Winesap	21.3	−60.0
		Red Delicious	14.8	−57.0
		Average	18.0	−58.5
578 oil	3 gal.	Winesap	32.9	−32.6
		Red Delicious	65.3	+24.1
		Rome	39.7	−58.7
		Average	65.6	−33.6
Systox 48.1% Em	0.25 pt.	Rome	43.9	+4.0
No insecticide	—	Winesap	84.4	+45.4
		Red Delicious	86.2	+7.9
		Average	85.3	+26.6

[1] Average number of apples per tree: Winesap 3067, Red Delicious 4281, and Rome 1344.

Table 3.—Control of Forbes scale, Knox County Orchard, Vincennes, Indiana, 1952. An average of 2218 apples per tree.

Insecticide	Pounds per 100 Gallons	Per Cent of Fruit Infested
CS-708 25% WP on tobacco stems	3	0.5
CS-708 25% + parathion 3% WP	1.5	0.1
Parathion 15% WP	1.5	0.05
DDT 50% WP	2	29.2
None (fungicide only)	—	22.1

Applied at a 3 per cent level with blood albumin as the emulsifier, the 1526 oil gave better control than the 1519 oil, suggesting that paraffinic oils with high viscosity are the most efficient. However, both these oils were better than the 578 oil. Control with 1526 oil was inferior to that obtained with Metacide, parathion, or malathon applied in one or more cover sprays.

Limited data indicating that CS-708 (Dilan) may control Forbes scale was secured in another series of plots in the Knox County orchard in 1952. Plots consisted of single Turley trees replicated three times. No dormant sprays were applied.

Eight applications were made starting at calyx time—on May 1, 9, and 21, June 4 and 18, July 9 and 29, and August 19. Harvest data (Table 3) show that where DDT and fungicide only were used Forbes scale built up so that at least one-fifth of the fruit was infested. Where CS-708 was used alone or in conjunction with parathion 0.5 per cent or less was infested. This reduction approached that secured where parathion was used throughout the season.

SUMMARY.—Forbes scale (*Aspidiotus forbesi* Johns) has become more abundant in fruit plantings of the Midwest since 1946. A survey covering sections of Indiana, Illinois, Kentucky, and Tennessee, made early in 1951, showed it to be the predominant species in apple, plum, and cherry orchards, and also present in one peach orchard. The rapid build-up of this scale and decline of San Jose scale, formerly prevalent, are attributed to the killing off, by DDT and other chlorinated hydrocarbon insecticides, of predators that formerly checked Forbes scale, control of San Jose scale with DDT, and light winter mortality of Forbes scale due to a succession of mild winters.

In studies and observations from 1950 through 1952, parathion, malathon, and Metacide used in summer applications were the most effective. Several covers with light concentrations of parathion or two early-season covers with a higher concentration were more effective than one application at a high concentration or two late applications at high concentrations. Dormant oil sprays reduced Forbes scale but did not give complete control. A paraffinic oil with a viscosity of about 150 seconds Saybolt was more effective than a lighter oil of this type or a naphthenic oil. In limited tests CS-708 held scale at a low level where 0.75 pound to 100 gallons was used in eight summer applications. Materials that gave poor reductions of Forbes scale or none at all were endrin, EPN, Systox, the triethanolamine salt of dinitro-*sec*-butylphenol, and diethoxyphosphinothioyl ethyl ethylphosphonate.

LITERATURE CITED

Chandler, S. C. 1950. Curbing the plum curculio. Trans. Ill. State Hort. Soc. **84:** 111–35.

Flint, W. P. 1923. Shall we change our recommendations for San Jose scale control. JOUR. ECON. ENT. **16**(2): 209–12.

Johnson, W. G. 1896a. Preliminary notes on five new species of scale insects. Ent. News **7**(5): 150–2.

Johnson, W. G. 1896b. Notes on new and old scale insects. U. S. Dept. Agr. Div., Ent. Bul. **6**(N.S.): 74–8.

Johnson, W. G. 1896c. Descriptions of five new species of scale insects, with notes. Bul. Ill. State Lab. Nat. Hist. **4:** 389–95.

McAlister, H. J., L. F. Steiner, S. A. Summerland, and J. E. Fahey. 1949. Control of apple insects and mites. Trans. Ind. Hort. Soc. **89:** 37–46.

O'Neill, W. J. 1951. DDT and parathion for San Jose scale control. JOUR. ECON. ENT. **44**(5): 709–11.

Steiner, L. F., S. A. Summerland, H. J. McAlister, and J. E. Fahey. 1948. Results of tests with various insecticides for the control of codling moth, red-banded leaf roller, orchard mites and scale. Trans. Ind Hort. Soc. **88:** 48–67.

Fringe Benefits from Plant Quarantines[1]

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There are two alternatives to adoption by a country of a system of plant quarantines. The most stringent one, and incidentally the greatest barrier to trade, would be an embargo on all plant imports. At the other extreme, a country could show utter disregard for the multitude of foreign pests it might receive by opening its borders to the free entry of all plant material. Thus a country can totally restrain foreign trade in such materials, or it can allow free trade in these commodities.

Just what do most countries do? Official records fail to show any country that enforces a flat embargo on the entry of plant imports. However, a few nations apparently think that they can get along satisfactorily without any restrictions on the entry of possible pest carriers. One such country is the Republic of Honduras in Central America. This Republic has no plant-quarantine import restrictions other than a decree that prohibits the importation of used coffee sacks or merchandise packed in such sacks. Siam is in the same category. Every other foreign country has some form of plant quarantine. These quarantines vary from the rather complex import regulations of Mozambique to the relatively concise and simple restrictions of the Chinese Republic, now about to be revised by the Chinese Government on Formosa.

Forty years ago the United States formulated its policy toward dangerous foreign insects and plant diseases by passing the Plant Quarantine Act. The original Act of August 20, 1912, has been amended six times. But its sections 5 and 7, respectively restricting and prohibiting the importation of plants or plant material, are as originally written, except for an addition to take care of importations by the Department of Agriculture.

Basically the Plant Quarantine Act and actions taken under it have resulted in the importation under adequate safeguards of huge quantities of plants and plant material. In 1951, for example, there were imported more than 500,000,000 bulbs and nearly 4,500,000 items of nursery and greenhouse stock, with an estimated value exceeding $10,000,000. More than 104,000,000 pounds of unmanufactured cotton worth $42,000,000 entered under the restrictions of our cotton regulations. Imports of less value were 17,000,000 pounds of fruits and 272,000,000 pounds of potatoes. Inspectors examining these imports and other material made nearly 7,700 interceptions of dangerous foreign insects and plant diseases.

These accomplishments, along with the safeguarding of interstate movement of host materials from quarantined sections of the United States, are the normal, expected results of plant-quarantine operation. There are, in addition, some incidental benefits to the buying public, to growers, and to market practices. These fringe benefits are well known to plant-quarantine inspectors and to the growers or importers benefited, but they are not widely known to the public. Most of the following illustrations are recorded for the first time.

One prominent grower and shipper of citrus, vegetables, and cotton in the Lower Rio Grande Valley of Texas was quoted in a Houston newspaper as saying that the Valley should erect a monument to the pink bollworm because the agricultural practices which the farmers are following to meet the requirements of the quarantine have meant millions of dollars of added income to this prolific area. The grower said that the average seasonal production of cotton in the Valley before the pink bollworm invasion was 213 pounds of lint per acre, and that within 5 years after control regulations were imposed the average production was 342 pounds. What this grower was referring to, of course, were the State quarantine regulations that have forced growers to adopt cultural practices—practices that their self-interest should have led them to adopt anyway. The regulations have made it obligatory to follow rigid control measures. Probably the most effective of these measures is the early cutting and shredding of cotton stalks, so that the high temperatures at the soil surface kill the pink bollworms and boll weevils in the

[1] Presented at the meeting of the American Association of Economic Entomologists at Philadelphia, Pa., December 15–18, 1952.

bolls. When this practice is followed by plowing to cover all stalks and crop debris, a high degree of control over this most destructive of the cotton insects is obtained.

Another change in our quarantine procedures appears destined to brighten up our parks and home gardens with finer and more colorful Dutch and Belgian flower bulbs. State plant-pest officials report that the recently initiated point-of-origin inspection of bulbs in the Netherlands and Belgium has resulted in a tremendous improvement in the quality of bulbs received in this country. Our plant-quarantine inspectors work side by side with those in the two countries. The Dutch and Belgian inspectors thereby learn what our requirements are before the bulbs are packed. When the consignments arrive in this country, there is no inspection delay at the piers; the cases go directly to the receiver. Initially superior bulbs thus make an uninterrupted trip from the port of departure with no intervening plant-quarantine handling.

Let us look at two instances where plant growers are reaping an additional benefit from quarantine soil treatments. One means of securing white-fringed beetle certification for nursery stock and farm crops in the Southeastern States is through the application of DDT to the growing area. This treatment not only kills any white-fringed beetle grubs that may be present, but also destroys many other injurious soil insects, and results in higher yields and a thriftier crop. Similar results have been obtained in the treatment of bench soil in greenhouses for golden nematode control. Such soil is given a dosage of D-D mixture as a nematocide. This treated bench soil produces prolific crops of first-quality flowers, far superior to those grown in untreated soil. It is not hard to enforce quarantines when growers get results like these.

Some of our import restrictions on Mexican fruits, through their selectivity, are providing all of us with better oranges and grapefruit for our breakfast table. Particularly responsible are the Bureau quarantines against entry into the United States of the eggs and larvae of fruit flies. Bureau-approved treatments involve heating the fruit with saturated vapor at 110° F. Two treating schedules are authorized. One calls for a gradual approach period of 8 hours, during which the center of the fruit must be heated to the required temperature, followed by a holding period of 6 hours, during which a constant temperature is maintained. The second and quicker treatment calls for a 6-hour approach period and a 4-hour holding period. Either schedule may be used in treating oranges and tangerines. The longer schedule is authorized for grapefruit and Manila mangoes. The heat-treating chambers are also used as coloring rooms.

The selectivity of this vapor-heat treatment arises from the provision that only commercially sound fruit, free of leaves and other debris, may be treated. There is a further requirement that tangerines must have tight skins and be free from air pockets or puffiness. Such air cavities may protect fruit fly larvae and reduce the chances of their being killed. As reported by Baker (1952), citrus fruit that is thorn-pricked, bruised, lightly infested by fruit flies, or similarly injured turns brown over the injured spot as a result of vapor-heat sterilization, and this fruit is easily culled when it is later run over the graders. Unsterilized fruit with such injuries is undetectable at the time of packing, but it breaks down rapidly en route to market. The treatment therefore reduces transportation losses, and you and I get fruit of much higher quality.

Late in 1947 and again in 1949 improved methods of cold treatment for imported fruits were authorized. These methods were especially useful to importers bringing in grapes, pears, plums, and apples from Argentina or the Union of South Africa (Richardson 1952). Several alternate schedules ranging from 12 days at 34° F. to 20 days at 35° were provided, dependent upon the species of fruit fly that might be infesting the fruit. Fruit to be imported must be cooled to the prescribed temperature either at a dockside refrigeration plant prior to loading or aboard the carrying vessel prior to departure. Approved, continuous-recording thermographs are required in each carrying vessel. Thermograph records must show that the fruit has been held at or below the minimum temperature for the required number of days.

Before this method of in-transit treatment was authorized, much less effort was

made by steamship companies to maintain uniform refrigeration. Fluctuations in temperatures resulted in considerable spoilage so that large quantities of fruit had to be dumped, or sorted and repacked. Reports from importers are that the newer methods result in a minimum of spoilage and a much higher quality of fruit for the American market. Since less spoilage also means fewer damage claims to be settled by the steamship lines, fruit importers and steamship lines are getting a bonus from the adoption of an improved quarantine procedure.

Benefits from quarantines are also found in the Christmas-tree industry. For many years it was required that Christmas trees cut in the New England States infested with the gypsy moth be inspected for egg clusters before the trees could be moved out of the regulated area. Methyl bromide as a means of destroying egg clusters was introduced in October 1942. It was almost immediately apparent to inspectors supervising these fumigations that there were additional benefits. There was much less needle drop when trees were fumigated. Later tests confirmed this observation (Latta 1945), and also showed that treated trees keep their normal green color longer. Fir trees respond better than spruce. These findings have been especially useful in answering the claims of Christmas-tree brokers that quarantine fumigation has caused trees to shed their needles.

A Japanese beetle quarantine treatment, authorized for certification purposes in 1949, is being used as somewhat of a trade secret to produce superior plants. A prominent eastern wholesale plant specialist spends about $200 annually for the necessary ingredients to treat about 270,000 potted plants with methyl dibromide-chlordane dip. This number is about 75 per cent of his annual production, with an estimated value of $100,000. The cost of the ingredients per plant is a minute fraction of one cent. This grower is enthusiastic about the results. He states that dipping the plants in the prescribed solution destroys certain root-injuring insects—over and above killing all stages of the Japanese beetle present. In addition, dipping the plants just before shipment assures that they are sufficiently moist to withstand long-distance shipment. Consequently his plants reach customers in better condition. Sales are easier to make and volume is increased. He states that, were the quarantine to be abandoned, he believes he would continue dipping his plants, using the same ingredients for the destruction of all insect grubs and eggs present. This grower is obviously finding some benefits that overcompensate for any annoyance from quarantine requirements.

An unusual incidental angle of the Japanese beetle quarantine is the excuse it occasionally gives a plant grower to limit his market. Prior to 1940, many eastern wholesale plant growers considered the cost of complying with the certification requirements excessive. In those days their advertisements in the horticultural trade magazines often contained the qualification, "Beetle zone only" (Sherman 1947), indicating that their plants were not eligible to move out of the Japanese beetle regulated area. When it became possible to destroy any invading grubs by pouring on a few ounces of inexpensive chemical solution just before the plants are packed for shipment, the treating cost became negligible. Plant growers rapidly adopted this or some other improved method to their liking. But "Beetle zone only" continues in a few growers' advertisements. Its intent has changed, however. Repeated inquiries of such advertisers have disclosed that the growers usually have a limited supply of the particular item offered. By limiting purchasers to those in the beetle area, they can dispose of their material at low transportation charges and avoid having to refuse many orders that arrive after the stock is exhausted. This is an effective trade dodge in the guise of a quarantine restriction.

A plant quarantine has caused a major change in the marketing of Long Island potatoes. The New York State golden nematode quarantine compels Long Island growers to use paper bags in marketing potatoes grown in close proximity to golden nematode infestations. Prior to this requirement, Long Island was among the few potato-growing areas continuing to market all of its potatoes in 100-pound burlap bags. Soon after affected growers began packing their potatoes in paper bags, other growers adopted the practice and this enabled them to market their product through the chain stores in 10-,

15-, and 50-pound paper bags. Now most of the Long Island growers have adopted this improved marketing procedure.

Normal operation of plant quarantines must by its very nature impose some arbitrary regulations on imports that may introduce foreign pests. Additional regulations are needed to confine or control those foreign pests that have gained entry. But in many instances the existence of some important fringe benefits tends to make the regulations more palatable to those affected.

LITERATURE CITED

Baker, A. C. 1952. The vapor-heat process. *In* Insects, the Yearbook of Agriculture, 1952, pp. 401–4.
Latta, Randall. 1945. Christmas tree quality improved by methyl bromide fumigation. JOUR. ECON. ENT. **38**(3): 398.
Richardson, Henry H. 1952. Cold treatment of fruits. *In* Insects, the Yearbook of Agriculture, 1952, pp. 404–6.
Sherman, Ralph W. 1947. Beetle zone only. Florists' Exch. **109**(8): 14.

Acaricides for Control of Tomato Russet Mite in California[1,2]

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The tomato russet mite, *Vasates destructor* (Keif.), has been a pest of tomatoes in California for about 10 years (Bailey & Keifer 1943). During this time sulfur has been found to give excellent control, and it has been used extensively and effectively in preventing losses by this pest. In the past few years many new acaricides and insecticides have appeared on the market, however, and it seemed advisable to compare the effectiveness of these new materials with that of sulfur on this pest. In view of these facts, 28 materials were tested for the control of the russet mite on infested tomato plants in the laboratory during the 1951–52 winter months.

MATERIALS AND METHODS.—For these tests large colonies of mites were maintained on stock tomato plants. Since these plants were soon destroyed by the mites, it was necessary to have a constant supply of new cultures available at all times. For these tests 250 seedling plants in the two-leaf stage were transplanted each week. Thirty of these plants were set in 8-inch pots and held for stock plants; the most uniform of the remaining plants were set in half-pint wax-paper cups and used for test plants. The stock plants were not infested until they were about 18 inches tall. As soon as the russeting symptoms appeared, mites were removed to infest other stock plants and the test plants.

The test plants were infested within 5 to 7 days after transplanting. The cups into which they were transplanted contained a 0.5-inch layer of peat moss on the bottom, a 0.5-inch layer of soil in the middle, and a 0.5-inch layer of sand on top. A hole was punched in the side of the cup, in the middle of the peet-moss level, to serve as a drain. The test plants were watered every other day. To keep the plant size to a minimum for convenience in handling, nutrient solution was applied only as necessary. It was possible to hold these plants for 2 months before the roots went through the bottom of the cup or the cup rotted apart.

Several methods have been developed for recovering small insects and mites from foliage by washing and filtering (Jones & Prendergast 1937). For the present tests a washing, filtering, and collecting method was devised in which an irritant, pyrethrins with MGK 264, was used to free the mites from the plants, and a wetting agent, polyoxyethylene sorbitol laurate,[3] was used to keep the mites in suspension.

The procedure used was the following: Between 20 and 30 grams of infested leaves were collected and placed in a liter of washing solution. After 30 seconds of stirring, the solution was drained off

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[2] Paper of the University of California Citrus Experiment Station, Riverside, California.
[3] *Atlox 1045;* Rohm & Haas Company.

into a No. 4 Büchner funnel and drawn through a sharkskin filter paper under vacuum. The mites in the solution tended to collect in spots on the filter paper over the holes in the funnel. After filtration, the paper was cut to separate the various spots of mites. As long as the filter paper remained damp, the movement of the mites was slight. While still damp, the pieces of paper were placed on the leaves of the plants. After the paper dried most of the mites moved onto the leaves, infesting them. It was observed that the process killed some of the mites, but this loss seemed to have little effect in these experiments.

In a test made to measure the value of various materials in the washing solution, leaf samples were collected from 35 infested stock plants, and the leaves were quartered and mixed together. This leaf sample was divided into 16 subsamples, each of which was placed in a separate 250-ml. beaker. Four of these subsamples were selected at random for treatment with the following aqueous washing solutions: (1) pyrethrins plus MGK 264 plus wetting agent, (2) pyrethrins plus MGK 264, (3) wetting agent alone, and (4) plain water. The treated samples were filtered as described above, and the mites were counted on many equal-sized unit areas of filter paper for each treatment replicate. When the data were analyzed statistically, the pyrethrins-MGK 264-wetting agent solution was found to contain the most mites and plain water the least. The other treatments ranged between treatments 1 and 4 in effectiveness.

The infested tomato plants were treated with dust by means of a vacuum-type dust tower, consisting of a 12-inch bell jar, the bottom of which was fitted with a rubber gasket, placed upon a marble slab. The vacuum line was equipped with a stopcock, dust trap, and vacuum gauge. Most of the features of this tower (Fig. 1) have been described in other publications (Farrar *et al.* 1948, 1951; McCallan 1950, and Richards & Murphy 1949) and need not be repeated here.

Mite population records were made by examining an entire plant under a binocular microscope. After an over-all examination, the mite population was estimated on the basis of observed living mites and rated as follows:

Rating	*Mites*
0	None
1	1 to 6 (hard to find)

Table 1.—Relative effectiveness of various materials used as dusts in the control of the tomato russet mite, Vasates destructor (Keif.), on tomato plants in the laboratory.

DAYS EFFECTIVE AFTER TREATMENT[1]	MATERIALS USED AT DOSAGES OF		
	0.1 Gram	0.25 Grams	0.5 Gram
7	Aldrin, 2% Chlordane, 5% Compound CS-708, 5% DDT, 2.5% DMC, 1% Isodrin, 0.5% Malathon, 5%	Aldrin, 1% Aramite, 3% Chlordane, 2.5% Compound Q-137, 5% Heptachlor, 1% Malathon, 2.5%	Aramite, 1.5% Compound MR-30, 5% Heptachlor, 0.5% Lindane, 1% Methoxychlor, 5% TDE, 5%
15		Chlordane, 5% Compound CS-708, 5%	Aramite, 3% Compound Q-137, 5%
25	DDT, 5% Dieldrin, 2% Parathion, 1%	Aldrin, 2% DMC, 1%	Compound CS-708, 5%
Over 25	Compound K-6451, 5% Compound R-242, 10% Endrin, 0.5% Metacide, 0.5% Parathion, 0.5% Sulfur, 49% Toxaphene, 5%	DDT, 2.5% Dieldrin, 1% Isodrin, 1% Malathon, 5%	Aldrin, 1% Chlordane, 2.5% Compound R-242, 5% Heptachlor, 1% Isodrin, 0.5% Malathon, 2.5%

[1] At the end of these periods, the specified treatments began losing their effectiveness, and the mites were able to become established and to increase in numbers. "Over 25" indicates almost perfect control still in effect at close of experiment.

2 7 to 25 (easily found but plant not damaged)
3 26 or more (plant showing russeting symptoms)

Plants selected for treatment had a population rating of 1. Counts were made 7, 15, and 25 days after treatment. If counts were made sooner than 7 days after treatment. If counts were made sooner than 7 days after treatment, it was difficult to differentiate between dead and live mites.

In these tests studies were made of dosages required for immediate and residual control of the mites. Most materials were tested at percentages suggested for field use and at 0.5-, 0.25-, 0.1-, and 0.05-gram dosages. If the material gave perfect control at the 0.05-gram dosage, the concentfation was cut in half by blending with pyrophyllite and tested again.

RESULTS.—In these experiments 1700 tomato plants were used in testing 28 different materials. The concentration, dosage, and terms of effectiveness of 22 of these materials are given in table 1. These records show that at the 0.1-gram dosage, control was obtained for 25 days with 49 per cent sulfur, 0.5 per cent parathion, 0.5 per cent Metacide, 5 per cent toxaphene, 5 per cent *p*-chlorophenyl *p*-chloro-benzene-sulfonate (K-6451),[4] 5 per cent endrin, and 10 per cent Compound R-242. Perfect control was also obtained for 25 days with 2.5 per cent DDT, 1 per cent dieldrin, 1 per cent isodrin, and 5 per cent malathon at the 0.25-gram dosage. At the 0.5-gram dosage, 1 per cent aldrin, 5 per cent isodrin, 2.5 per cent malathon, 5 per cent Compound R-242, 2.5 per cent chlordane, and 1 per cent heptachlor also gave perfect control for 25 days.

Poor or no control was obtained at any dosage with Aramite, Compound CS-708, DMC, lindane, methoxychlor, bis-(*p*-chlorophenyl) ethynyl carbinol (Compound MR-30), Compound Q-137, or TDE.

Systox and schradan applied by irrigation at the rate of 10 cc. per pot (concentration 0.001 gram per liter) gave perfect control of the mites for the term of the experiment.

Four diluents, attapulgite, pyrophyllite, atomite, and hydrated lime, were used at full strength at the 0.5-gram dosage and were found to be comparatively ineffective on the mites.

SUMMARY.—In laboratory experiments 28 materials were tested for effectiveness in controlling the tomato russet mite, *Vasates destructor* (Keif.). Materials were applied as dusts at varying dosages and concentrations, by means of a vacuum-type dust tower, to artificially infested tomato plants. In these experiments parathion, Metacide, Compound R-242, toxaphene, *p*-chlorophenyl *p*-chloro-benzene sulfonate (K-6451), and endrin appeared to be as effective as sulfur, which is the recommended material. Malathon, isodrin, dieldrin, DDT, heptachlor, chlordane, and aldrin were nearly as effective as sulfur. Aramite, Compound CS-708, DMC, lindane, methoxychlor, bis-(*p*-chlorophenyl) ethynyl carbinol (Compound MR-30), Compound Q-137, TDE and four diluents were relatively ineffective.

[4] *Ovotran.*

LITERATURE CITED

Bailey, S. F., and H. H. Keifer. 1943. The tomato russet mite, *Phyllocoptes destructor* Keifer: its present status. JOUR. ECON. ENT. **36**(5): 706–12.

Farrar, M. D., W. C. O'Kane, and Howard W. Smith. 1948. Vacuum dusting of insects and plants. JOUR. ECON. ENT. **41**(4): 647–8.

Farrar, M. D., and John K. Reed. 1951. Evaluation of cotton insecticides. JOUR. ECON. ENT. **44**(6): 943–6.

Jones, Laurence S., and David T. Prendergast. 1937. Method of obtaining an index to density of field populations of Citrus Red Mite. JOUR. ECON. ENT. **30**(6): 934–40.

McCallan, S. A. E. 1950. Factors influencing deposition in vacuum bell jar duster. Boyce Thompson Inst. Contrib. **16**(1): 27–37.

Richards, M. C., and Douglas Murphy. 1949. The vacuum duster for applying fungicides and inoculum to plants. Phytopath. **39**(1): 20.

SCIENTIFIC NOTES

A Strepsipteran Parasite of the Three-Cornered Alfalfa Hopper[1]

C. R. JORDAN[2]

Parasitized individuals of the three-cornered alfalfa hopper, *Spissistilus festinus* (Say), were observed by the writer near College Station, Texas, in the early spring of 1950.

Increasing numbers of parasitized hoppers were found later in the spring and summer near College Station and near Shreveport, Louisiana. The parasites were determined as Strepsiptera, but no reference to a Strepsipteran parasite of *S. festinus* could be found in the literature.

Specimens of the parasite were sent to Dr. W. D. Pierce of the Los Angeles County Museum and were determined as *Membracizenos jordani* Pierce, new genus and new species (1952). Dr. Pierce stated (in correspondence) that this was the first record to his knowledge of a Strepsipteran parasite of the Family Membracidae in America.

Periodic sweepings of alfalfa and soybeans during July and August, 1950, were examined for parasitized alfalfa hoppers. Only those hosts showing the parasites externally were recorded as being parasitized. The examination of 12 samples of the host insect over a 6 weeks period revealed a variation of 3 to 30 per cent parasitism. A total of 1,090 hoppers was examined and 124 (14.13 per cent) showed the parasites externally. As many as four parasites were found protruding between the abdominal sclerites of an individual host. Parasitism occurred at a much lower level during 1951. Only 15 parasitized hoppers were found out of a total of 4,336 individuals examined over a period of 5 months.

The sex of 87 parasitized individuals and the sex of the parasites were determined. Slightly more female hosts and more male parasites were found. Male parasites were distributed in about equal numbers in hosts of each sex, but more female parasites were found in female hosts.

Dissections of adult alfalfa hoppers have revealed as many as 6 larval parasites developing in a single host insect. The percentages of parasitized individuals given above would have been much higher if those parasites developing internally had been recorded. Parasitism by *M. jordani* was not proved to cause death of the hosts, but no parasitized female was ever found to contain eggs. It is believed that the high rate of parasitism was a contributing factor in holding down the population of the three-cornered alfalfa hopper to relatively low numbers in the area studied during 1950.

LITERATURE CITED

Pierce, W. D. 1952. A new Strepsipterous parasite of Membracidae. Bul. So. Cal. Acad. Sci. **51**(1): 4–8.

[1] Technical contribution No. 1658, Texas Agricultural Experiment Station. (Observations in Louisiana were made while the author was a member of the Louisiana Agricultural Experiment Station Staff.)

[2] Extension Entomologist, University of Georgia. Formerly Research Assistant, Texas Agricultural Experiment Station.

DDT, Methoxychlor, and Pyrethrins-Piperonyl Butoxide Against the Hairy Spider Beetle in Warehouses[1]

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In Western Canada the hairy spider beetle, *Ptinus villiger* (Reit.), is an important pest in warehouses in which flour and other cereal products are stored. The biology of these spider beetles and methods for their control were first described by Gray (1933). More recently Smallman (1948) reported on warehouse experiments carried out with six residual insecticides for control of this insect. DDT in oil solution, or in water suspension, and benzene hexachloride in oil solution were equally effective in controlling infestations. However, the musty odor associated with benzene hexachloride was a disadvantage and DDT was recommended (Smallman & Gray 1948).

The reluctance of some cereal processing firms to adopt DDT for use in warehouses containing cereal products prompted trials with two residual insecticides of lower mammalian toxicity. Experiments were conducted for two years in country warehouses infested with the hairy spider beetle. During the first year comparisons were made between DDT and pyrethrins-piperonyl butoxide applied in oil solutions, the second year between DDT and methoxychlor applied as water suspensions.

METHODS.—In April, 1949, 18 warehouses in Manitoba were treated with DDT and pyrethrins-piperonyl butoxide. Nine of these were selected at random for retreatment in June. No warehouses were included in the experiments that had been treated previously with a residual insecticide.

Technical grade DDT was dissolved in deodorized kerosene to give a 2.5 per cent (w:v) solution. Pyrenone concentrate was obtained from U. S. Industrial Chemicals, Baltimore, Maryland, as a T 143 formulation stated to contain 10 gm. of piperonyl butoxide and 1 gm. of pyrethrins per 100 ml. of base oil. This was diluted with deodorized kerosene to give 2.5 per cent (w:v) piperonyl butoxide and 0.25 per cent (w:v) pyrethrins.

The floor of each warehouse was marked off into three equal areas, each of which was assigned on a random basis for treatment with either DDT or pyrethrins-piperonyl butoxide, or left as an untreated control area. The insecticides were applied to the floor and the lower five feet of the walls with a knapsack pressure sprayer regulated to give a coarse spray. By weighing the sprayer at intervals during application it was possible to dispense approximately 100 mg. of DDT or 100 mg. of piperonyl butoxide and 10 mg. of pyrethrins per square foot of floor and wall surface.

Comparative tests with DDT and methoxychlor

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Table 1.—Mean numbers of spider beetles obtained from three 7-pound sacks of flour per area.

Date of Application	No. of Warehouses	Treatment				
		DDT Oil	Pyrethrins-Pip. But. Oil	DDT Water	Methoxychlor Water	None
Apr. 1949	9	10.4	44.1	—	—	199.8
Apr. and June, 1949	9	6.4	14.3	—	—	443.6
Apr. 1950	9			32.3	117.9	245.8
Mean		8.4[1]	29.2[1]	32.3[2]	117.9[2]	

[1] Difference required for significance, 5% level: 9.4.
[2] $P<0.01$

were carried out the following year in nine of the 18 warehouses. A single treatment of each insecticide was applied in April. Areas treated with DDT the previous year were again treated with DDT, and areas treated previously with pyrethrins-piperonyl butoxide were treated with methoxychlor. Both DDT and methoxychlor were obtained in the form of 50 per cent (w:v) wettable powders and were diluted with water to give a 2.5 per cent (w:v) suspension. The insecticides were sprayed on the floor and the lower five feet of the walls as before. Spraying was regulated to give approximately 100 mg. of toxicant per square foot of surface.

Effectiveness of each treatment was assessed by the number of spider beetles sifted from test sacks of flour placed in each warehouse. Three 7-pound sacks of white patent flour were placed at random in each of the two treated areas and in the untreated area immediately after the treatments. The sacks remained in the warehouse throughout the oviposition period, from April to July (Smallman & Gray 1948), and were collected in October for sifting.

Analysis of variance was carried out with all data. An appropriate transformation, *log* $(x+1)$, was applied to data obtained from treatments with DDT and methoxychlor.

Results and Discussion.—The mean numbers of spider beetles sifted from test sacks distributed in the treated areas of the warehouses are shown in table 1.

There was a significant difference between warehouse areas treated with DDT and pyrethrins-piperonyl butoxide, but no significant difference between one and two applications of each insecticide. Student's *t* test demonstrated significant differences ($P<0.05$) between areas receiving one treatment with pyrethrins-piperonyl butoxide (April) and areas treated once and twice with DDT. Areas treated twice with pyrethrins-piperonyl butoxide were not significantly different ($P>0.3$) from areas treated twice with DDT. Although the difference between one application and two applications was not significant for either treatment, some credence should be given to the apparent reduction in number of spider beetles resulting from a second application of pyrethrins-piperonyl butoxide because the difference between one and two applications of this insecticide ($P=0.09$) approaches significance. The greater number of insects obtained from untreated areas in warehouses receiving two applications of DDT and pyrethrins-piperonyl butoxide resulted mainly from an abnormally high count (1,953) in a single warehouse.

The results also showed that a single application of DDT was significantly more effective than one of methoxychlor ($P<0.01$).

Summary.—Both DDT and pyrethrins-piperonyl butoxide were highly effective in preventing infestation of sacked flour by the hairy spider beetle in warehouses. Two applications of DDT in April and June were no more effective than one application of DDT in April. Two applications of pyrethrins-piperonyl butoxide in April and June gave about the same control as one application of DDT; the difference between two applications of pyrethrins-piperonyl butoxide in April and June and one application in April was significant at the 9 per cent level. A single application of DDT was better than single applications of pyrethrins-piperonyl butoxide or methoxychlor.

Literature Cited

Gray, H. E. 1933. The hairy spider beetle, *Ptinus villiger* Reitt., in Canada. Proc. World's Grain Exhib. and Conf., Canada, **11**: 553–61.

Smallman, B. N., and H. E. Gray. 1948. The control of spider beetles in Western Canada. Canadian Natl. Millers' Assoc. March.

Smallman, B. N. 1948. Residual insecticides for the control of spider beetles in cereal warehouses. Jour. Econ. Ent. **41**: 869–74.

Timing Plum Curculio Sprays on Apple

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The usual stage in the development of apple at which poisoning for the plum curculio, *Conotrachelus nenuphar* (Hbst.) is begun is at the calyx stage, when at least 75 per cent of the petals have fallen. In order to coincide with the first application for codling moth, it should be completed before the calyx cups close. Studies in Illinois in the past two seasons indicate that much better control may be obtained by starting sprays in what is known as the pink or cluster bud stage, just before the blossoms open.

The plan of procedure in this study was to record population of adult curculios throughout the season, to correlate the development of several varieties of apple with peach development, and to conduct spraying tests.

The Occurrence of Plum Curculio on Apple.—In 1951 and 1952 trees were jarred and curculios caught on sheets placed beneath the branches in three widely separated orchards in southern Illinois.

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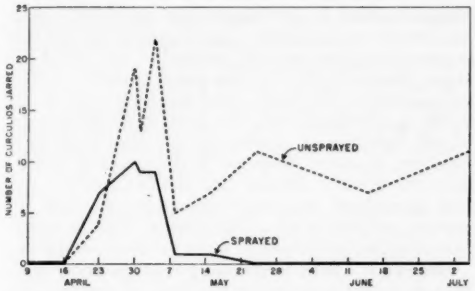

FIG. 1.—Number of curculios jarred in sprayed and unsprayed blocks of apples, Jackson County, Illinois, 1951. Tree development and spray dates: April 6, Delayed dormant; April 9, prepink; April 24, full-pink; April 24, pink spray applied; April 30, full bloom; May 1, 25–50 per cent petals fallen; May 4, 90 per cent petals fallen, calyx spray; May 11, first cover spray.

These records, carried through the period of first brood attack, are shown in the following graphs, Figures 1 to 5. These graphs, with the accompanying data on development, show that for two seasons curculios first appeared in the pink stage or early bloom, depending somewhat on variety, reached a peak sometime in the blooming period, decreased rapidly to a much lower level within a week after petal fall, and were present in comparatively small numbers during the rest of the first-brood period.

CORRELATION OF APPLE AND PEACH DEVELOPMENT.—Since stage of development is used to determine times of spray application, a study was made in 1952 in a block of seven varieties of apple and in Elberta peach adjacent to determine times of the natural events in each variety and intervals between identical stages in different varieties. These data are given in table 1.

Table 1 shows differences of several days between the same stage in different varieties of apple.

The importance of the records on peach lies in the fact that for many years our jarring data in Illinois show first curculios appearing in Elberta peach

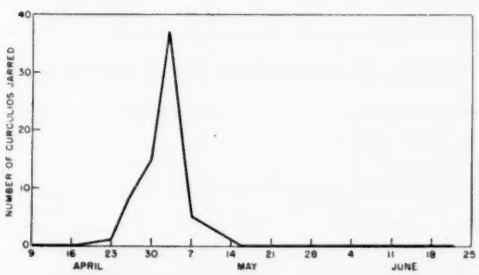

FIG. 2.—Numbers of curculios jarred from ten Transparent apple trees, Sauer orchard, Jackson county, Illinois, 1951. Tree development and spray dates: April 9, prepink; April 17, prepink to pink; April 23, full pink; April 25, 25 per cent blossoms open; May 1, full bloom; May 3, 50 per cent petals fallen; May 4, calyx spray applied; May 4, 75 per cent of petals fallen; May 14, first cover spray applied; May 23, second cover spray applied.

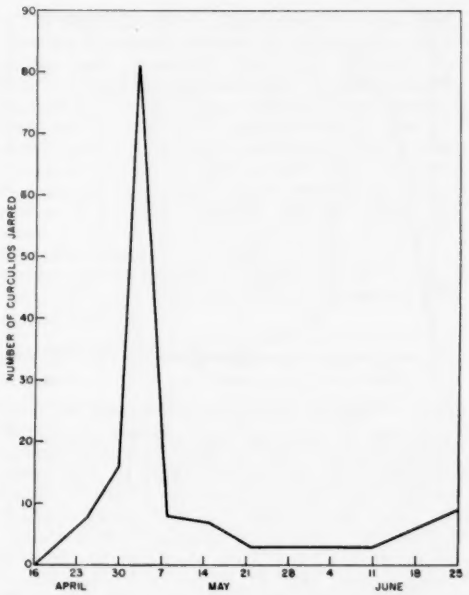

FIG. 3.—Numbers of curculios jarred from ten Transparent and Duchess apple trees, Beauman orchard, Johnson County, Illinois, 1951. Tree development and spray dates: Transparent—April 10, prepink; April 25, 25 per cent blossoms open; April 30, full bloom; May 3, 50 per cent petals fallen; May 3, calyx spray applied; May 8, 95 per cent petals fallen; May 11, first cover applied; May 22, second cover applied; June 6, third cover applied; Duchess —April 10, pink;—April 25, full bloom; April 30, 50 per cent petals fallen; May 3, 90 per cent petals fallen; May 3, calyx spray applied; May 8, all petals fallen; May 11, May 22, and June 6, same as for Transparent.

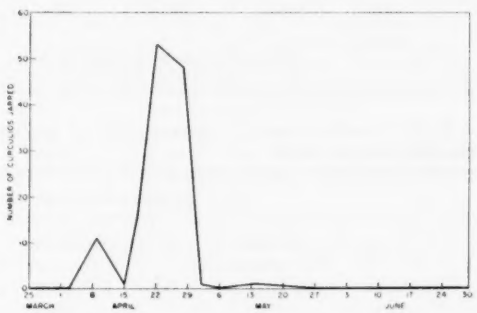

FIG. 4.—Number of curculios jarred from 30 apple trees, six varieties, Sauer orchard, Jackson County, Illinois, 1952. Tree development and spray dates: March 30, prepink; April 3, prepink; April 9, prepink to pink; April 15, pink spray applied; April 18, 7 to 53 per cent blossoms open; April 28, 65 to 100 per cent petals fallen, calyx spray, first stung apples; May 2, all petals fallen; May 5, first cover applied; May 12, second cover applied; May 23, third cover applied.

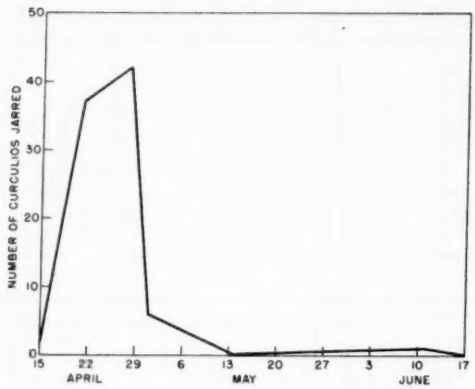

FIG. 5.—Numbers of curculios jarred from 10 Transparent and Duchess apple trees, Beauman orchard, Johnson County, Illinois, 1952. Tree development and spray dates: Transparent—April 15, pink spray; April 21, 75 per cent blossoms open; April 28, 75 per cent petals fallen; April 29, calyx spray applied; May 13, first cover, calyx cups closed; May 28, second cover; Duchess—April 15, 25 to 50 per cent blossoms open; April 21, 90 per cent petals fallen; April 28, all petals fallen, first stung apples; April 29, calyx spray applied; May 13, first cover, calyx cups closed; May 27, second cover.

orchards either in late bloom or at petal fall, and it has become an established practice to apply the first poisons for plum curculio control at the petal fall stage. First curculios in this peach orchard in 1952 were jarred in full bloom, April 9, which, as shown in Table 1, corresponded to the pink or prepink stages of all varieties of apples except the very early bloomer, Duchess. Because of the years of jarring data on peach in Illinois, and the two seasons' records given here, it is reasonable to assume that the pink or prepink stage is the normal time to expect first curculio occurrence in most varieties of apples.

SPRAYING TESTS.—Assuming that the point is established that appreciable numbers of curculios are present in apple orchards during the blooming period it would still need to be proved that a poison applied before the blossoms open, when there is very little growth to which it could adhere, would reduce the numbers sufficiently to prevent later injury. Observations showed that feeding and egg laying punctures were first found soon after petal fall and increased for at least two weeks after, despite sprays.

Spraying tests were conducted in 1952 in six large blocks of apples in five widely separated orchards in southern and western Illinois, beginning sprays in the pink stage in one block with a total of three or four applications, and in the calyx stage in another, with a total of two or three applications. The poisons used were mainly dieldrin, parathion, and chlordane. Fruit was checked in late May or in June when the

Table 1.—Development of seven varieties of apple and of Elberta peach. Jackson County, Illinois, 1952.

DATE	DUCHESS	WINESAP	DELICIOUS	GOLDEN DELICIOUS	JONATHAN	TRANSPARENT	BLACK TWIG	ELBERTA PEACH
3/25	Prepink	Dormant	Dormant	Dormant	Dormant	Dormant	Dormant	4% blossoms open
4/3	Pink	Prepink	Pink	Prepink	Pink	Prepink	Pink	90% blossoms open
4/9	15–20% blos. open	Prepink	Pink	Prepink	Pink	Pink	Pink	Full bloom; few petals fallen
4/11	Pink and 5% blos. open	Prepink	Pink	Pink	Pink	Pink	Pink	80% petals fallen
4/15	40% blos. open	Pink	Late Pink	Pink	Late Pink	Late Pink	Pink	95% petals fallen
4/18	72% blos. open	7% blos. open	53% blos. open	1% blos. open	15% blos. open	14% blos. open	12% blos. open	100% petals fallen
4/22	80% petals fallen	95% blos. open	60% petals fallen	62% blos. open	15% petals fallen	100% blos. open	17% petals fallen	Shucks cracking
4/28	100% petals fallen; calyx cups closing	87% petals fallen	100% petals fallen	65% petals fallen	93% petals fallen	77% petals fallen	98% petals fallen	¾ of fruit exposed; some shucks off
5/2		All varieties practically all petals fallen						Shucks mostly off
5/5		All varieties most of calyx cups closed						Shucks all off

Table 2.—Numbers and percentages of apples stung from plum curculio in five experimental orchards, Illinois, 1952.

ORCHARDS	APPLES EXAMINED PER BLOCK	POISONS STARTED IN PINK, APPLES STUNG		POISONS STARTED IN CALYX, APPLES STUNG		RATIO	POISONS USED
		No.	Per Cent	No.	Per Cent		
Sauer	1500	18	1.2	70	4.6	1 to 3.8	Dieldrin
Sauer	1100	25	2.3	78	7.0	1 to 3.0	Parathion
Beauman	1000	13	1.3	134	10.3	1 to 10.3	Dieldrin
Walkington	500	6	1.2	39	7.8	1 to 6.5	Dieldrin and lead arsenate
Perrine	500	4	0.8	14	2.8	1 to 3.5	Dieldrin and lead arsenate
Ringhausen	600	3	0.5	14	2.3	1 to 4.6	Chlordane
Average Ratio						1 to 5.3	

maximum injury from plum curculio was over. These records are summarized in table 2.

Table 2 shows that in every orchard, in both comparatively high and low levels of insect population, there were not less than three times as many stung apples in the blocks where first curculio poisoning was delayed until the calyx stage. In the case of the Sauer orchard, dieldrin proved to be superior to parathion.

To correlate reduction in insect population by poisoning with reduction of stings, equal numbers of trees were jarred in both blocks in the Sauer and Beauman orchards. The data are summarized in table 3.

Table 3.—Numbers of plum curculios jarred from equal numbers of apple trees in blocks in which poisons were started in the pink and the calyx stages.

Orchard	Curculios Jarred, Poisons Started in		Ratio, Pink to Calyx
	Pink	Calyx	
Sauer	25	94	1 to 3.7
Beauman	14	73	1 to 5.2

SUMMARY.—Plum curculio adults begin to appear on apple in the pink stage in most varieties studied, reach a peak some time during the blooming period, and decrease rapidly in numbers after petal fall. Identical stages of development in different varieties may occur as much as a week apart. Numbers of curculios and stings may be greatly reduced by beginning poison applications in the pink stage, the data showing over five times as many stung apples in blocks where poisoning was delayed until the calyx stage as where it was started in the pink stage.

Effect of Fertilizer on Rice Weevil Damage to Corn at Harvest

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Soil fertility and fertilization are known to influence the degree to which certain crops are damaged by insects. Wittwer & Haseman (1945) showed that the common greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouche), preferred New Zealand spinach grown in soils deficient in nitrogen and calcium. They stated that the injury to plants grown in low nitrogen levels was decreased by the addition of lime. Haseman (1946) reported that chinch bugs, *Blissus leucopterus* (Say), matured faster, lived longer, and produced more offspring when nitrogen was withheld from the nutrient solutions in which corn plants were grown. He stated that this host preference was observed in nature during the summer when the chinch bugs were numerous. The heaviest infestations were found on corn plants in a weakened condition due to low fertility of the soil. Arant & Jones (1951) reported that, as the rate of nitrogen to oats increased, the population of greenbugs, *Toxoptera graminum* (Rondani), decreased. The addition of lime also decreased the population of greenbugs, and the decrease was greatest where no nitrogen was used. The source and methods of applying the nitrogen had no effect on the populations.

Gadd (1943) noted increased damage to tea plants by the shot hole borer, *Xyleborus fornicatus* Egg., following increased amounts of nitrogenous, phosphatic, and potassium fertilizers. Surveys by Schoene (1941) showed that injury to apple trees in Virginia by the mealybug, *Pseudococcus comstockii* Kuw., was most severe in mature orchards that had been treated with nitrogenous fertilizers for several years and that no damage occurred on unfertilized trees, on young trees, or on trees which had always received a complete fertilizer. McGarr (1943) obtained results from field experiments which indicated that nitrogenous fertilizers caused a definite increase in the number of aphids, *Aphis gossypii* Glov., on cotton when the cotton was dusted with calcium arsenate.

Studies have been conducted in Alabama for four years on the effects of fertilizers applied to corn on damage by the rice weevil, *Sitophilus oryza* (L.). The results of some of these studies are reported in this paper.

METHODS.—The studies reported in this paper were conducted cooperatively with the Department of Agronomy and Soils of the Alabama Polytechnic Institute. Corn samples were taken from plots of corn grown in regular rate-of-fertilizer experiments. The plots consisted of 4 rows 30 feet long. Except where otherwise indicated, the treatments were replicated four times in randomized blocks. All of the corn from the plots was shelled and mixed. Samples of not less than 500 kernels were drawn from the corn from each plot. The rice weevil damage was determined by the acid fuchsin stain method of Frankenfeld (1948). In the experiment where husk cover was measured, the method described by Eden (1952) was used.

RESULTS.—*Nitrogen.*—The effect of nitrogenous fertilizer to corn on rice weevil damage was studied at the Plant Breeding Unit at Tallahassee in 1949 and at the Gulf Coast Substation at Fairhope in 1949, 1951, and 1952. The results are presented in tables 1, 2, and 3.

At Tallassee (Table 1) the rates of nitrogen per acre varied from 50 to 200 pounds. The rice weevil damage in this experiment was medium, averaging 21.3 per cent of the kernels. The greatest difference between any two rates of nitrogen was only 3.3 per cent, which was not significant. The weevil damage followed no particular pattern. The apparent trend toward better husk cover at the lower rates of nitrogen was not statistically significant. Therefore, in this experiment there was no relationship between rate of nitrogen and rice weevil damage.

Table 1.—Effect of four rates of nitrogenous fertilizer on rice weevil damage and husk cover of corn. Tallahassee, 1949.

Nitrogen per Acre	Weevil Damage	Husk Cover Rating
Lb.	Per Cent	
50	20.1	2.86
100	21.9	2.69
150	23.3	2.67
200	20.0	2.68

At the Gulf Coast Substation in 1949 (Table 2) the rice weevil damage was higher than at Tallahassee. In this study, where the rates of nitrogen varied from 48 to 120 pounds per acre, the average damage was 64.6 per cent of the kernels. The means of the two

varieties varied from 47.9 per cent at 48 pounds of nitrogen to 78.7 per cent at 120 pounds. The difference required for significance was 20.4 per cent; thus, there were differences between treatments. There was a significant correlation between the rate of nitrogen and the rice weevil damage. The damage increased as the rate of nitrogen increased. The correlation coefficient (r of Snedecor, 1946) was 0.965; 0.950 was required for significance at the 5 per cent level.

Table 2.—Effect of four rates of nitrogenous fertilizer on rice weevil damage to two varieties of corn. Gulf Coast Substation, 1949.

Nitrogen per Acre	Weevil Damage by Varieties		Mean
	Paymaster	Dixie 11	
Lb.	Per Cent	Per Cent	Per Cent
48	56.7	39.1	47.9
72	68.5	43.7	56.1
96	81.0	70.4	75.7
120	76.4	81.0	78.7
LSD, 5 per cent level			20.4

The results of the studies at the Gulf Coast Substation in 1950 and 1952 are presented in table 3. The rates of nitrogen varied from 30 to 120 pounds per acre. The average rice weevil damage for both varieties was 11.4 per cent in 1950 and 4.9 in 1952. The average over-all damage for both varieties in both years was 8.2 per cent. There were no significant differences in the weevil damage due to the nitrogen fertilizer in either variety for either year.

Table 3.—Effect of four rates of nitrogenous fertilizer on rice weevil damage to two varieties of corn. Gulf Coast Substation, 1950 and 1952.

Nitrogen per Acre	Weevil Damage by Varieties						
	Dixie 18		Dixie 11		Mean		
	1950	1952	1950	1952	1950	1952	Overall
Lb.	%	%	%	%	%	%	%
30	11.57	5.07	13.59	6.90	12.58	5.99	9.29
60	8.73	3.95	11.55	4.28	10.14	4.12	7.13
90	9.12	4.70	11.31	3.91	10.22	4.31	7.27
120	9.42	5.46	15.75	5.02	12.59	5.24	8.92

Phosphate.—The effect of phosphatic fertilizer to Dixie 11 hybrid corn on rice weevil damage was studied in an experiment conducted at the Gulf Coast Substation in 1949. The rate of P_2O_5 varied from 0 to 120 pounds per acre. Treatments were not replicated. The results are presented in table 4.

The average weevil damage at harvest was 6.6 per cent. There was no indication that the rate of phosphatic fertilizer influenced the rice weevil damage.

Potash.—The effect of varying rates of potassium fertilizer on rice weevil damage was studied at the Gulf Coast Substation in 1949. The study was made on an unreplicated rate of potash experiment on Dixie 11 hybrid corn. The results are presented in table 5.

The rate of K_2O varied from 0 to 80 pounds per acre. The average weevil damage in the experiment was 5.8 per cent of the kernels. There was no indication that the rate of potash influenced the rice weevil damage.

Table 4.—Effect of varying rates of phosphatic fertilizer on rice weevil damage to Dixie 11 hybrid corn. Gulf Coast Substation, 1949.

P_2O_5 per Acre	Rice Weevil Damage
Lb.	Per Cent
0	6.4
20	7.0
40	6.7
60	9.6
80	6.3
120	3.3

SUMMARY.—Studies were made for four years in Alabama on the effect of fertilizers to corn on rice weevil damage at harvest. In four experiments on the effect of varying rates of nitrogen only one revealed significant effects on weevil damage from the fertilizer. In that test the weevil damage increased as the rate of nitrogen increased. No significant effects were noted from varying rates of phosphatic and potassium fertilizers.

Table 5.—Effect of varying rates of potassium fertilizer on rice weevil damage to Dixie 11 hybrid corn. Gulf Coast Substation, 1949.

K_2O per Acre	Rice Weevil Damage
Lb.	Per Cent
0	5.8
20	4.1
40	3.0
60	9.6
80	6.3

LITERATURE CITED

Arant, F. S. and C. M. Jones. 1951. Influence of lime and nitrogenous fertilizers on the population of greenbugs infesting oats. JOUR. ECON. ENT. **44**(1): 121–2.

Eden, W. G. 1952. Effect of husk cover of corn on rice weevil damage in Alabama. JOUR. ECON. ENT. **45**(3): 543–4.

Frankenfeld, J. C. 1948. Staining methods for detecting weevil infestation in grain. U.S.D.A. Ent. and P.Q. ET-256.

Gadd, C. H. 1943. Does manuring reduce the damage caused by the shothole borer, *Xyleborus fornicatus* Egg. Tea Quart. **16**: 30–39.

Haseman, Leonard. 1946. Influence of soil minerals on insects. JOUR. ECON. ENT. **39**(1): 8–11.

McGarr, R. L. 1943. Relation of fertilizers to the development of cotton aphids in 1941–1942. JOUR. ECON. ENT. **36**(4): 640.

Schoene, W. J. 1941. Plant food and mealy bug injury. JOUR. ECON. ENT. **24**(2): 271–4.

Snedecor, G. W. 1946. Statistical Methods. Iowa State College Press. 138–168.

Wittwer, S. N. and Leonard Haseman. 1945. Soil nitrogen and thrips injury on spinach. JOUR. ECON. ENT. **38**(5): 615–6.

Leafhopper Control with Methoxychlor and Parathion to Increase Alfalfa Hay Production

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Methoxychlor and parathion have been found effective for the control of the leafhopper, *Empoasca fabae* (Harris), on alfalfa in Wisconsin for several years. Both insecticides apparently have a limited residue hazard. Label claims have been approved by Federal Agencies for the application of methoxychlor up to 7 days and parathion up to 15 days before harvest or grazing. Therefore, these insecticides were recommended in 1952 for use on forages in Wisconsin.

In order to demonstrate further their effectiveness for leafhopper control and obtain information on forage yields affected thereby, spray demonstrations were conducted cooperatively between research and extension workers and interested farmers. It should be mentioned that leafhopper populations were higher in 1952 than during the two previous seasons. Many alfalfa fields in southern and central Wisconsin were badly stunted and yellowed by leafhopper attack, especially where the first crop had been removed by an early cutting.

Sixteen second-growth alfalfa fields were sprayed with emulsions of 1 pound technical methoxychlor[2] per acre. Also included in six of these fields were plots sprayed with 4 ounces technical parathion per acre. Low volume sprayers were used to make the application at about 10 gallons per acre. The fields varied in size from 2 to 10 acres, but usually were about 5 acres. Each field was divided so that the sprayed plot and untreated check were equal. Sweepings were made two weeks after treatment in order to determine the insect control.

There was considerable variation in the second growth condition of the fields at the time the insecticide was applied. The height of the alfalfa when sprayed is roughly indicated by the management of the first cutting, since this determined the amount of re-growth: thus, alfalfa with an early first cutting was about 12″ tall, middle cutting was about 6″ and late cutting was stubble.

Insect counts are given in tables 1 and 2. In addition to the leafhopper, combined counts are given for *Adelphocoris lineolatus* (Goeze), *A. rapidus* (Say) and *Lygus oblineatus* (Say), since these mirids also are injurious to alfalfa. The data clearly show the consistent effectiveness of methoxychlor and parathion for leafhopper control. In Table 2 lack of control in the late-cut fields should not be attributed to failure of insecticide, because these fields were only stubble when sprayed and the adults collected were probably migrants. The data show that methoxychlor gave no control of adults or nymphs of mirids and that parathion controlled mirid nymphs fairly well, but did not control the adults. It should be mentioned that in most fields at 2 weeks after spraying the treated plots were uniformly normal in color and clearly marked off from the leafhopper-yellowed alfalfa in checks. The symptoms of mirid damage was recognizable in both check and treated plots, but largely masked in check plots by the more striking appearance of the yellowed alfalfa.

The data support the observation that a count of nymphs in alfalfa gives a good measure of insectidal effectiveness. Alfalfa is subjected to considerable migration of adults, even when plots are very large, and many of the adults collected at 2 weeks may have been migrants into plots after the toxicity of the insecticides was gone.

Several farmers harvested their fields so that the plot yields given in table 3 were obtained. Data are comparative between plots, but do not represent per acre production. All of the treated plots produced more hay than the untreated checks. On the average the increased yields were 120 per cent, with a range from 38 to 300 per cent. Since fertility, age of stand,[3] cutting regrowth, insect infestation and harvest date differed considerably from field to field, the variability in yield is to be expected. It is believed that the increase in hay production was largely a result of leafhopper reduction by the insecticides, since mirids were not controlled adequately. The higher production generally shown in the parathion plots may be attributed to better mirid control given by that in-

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[2] Mariate 2MR. Acknowledgment is made to E. I. DuPont de Nemours and Co., who provided the insecticide used in the demonstrations.

[3] In the younger stands of alfalfa, red clover was often present, and this plant is not susceptible to leafhopper and mirid injury to the extent that alfalfa is damaged.

Table 1.—Leafhopper and mirid control at 14 days in alfalfa fields sprayed with methoxychlor 1952.

		Number of Insects per 50 Sweeps of a 15″ Net[1]									
		Leafhoppers					Mirids[1]				
		Treated		Check		Per Cent Red.	Treated		Check		Per Cent Red.
Farm and County	Cutting	Nymphs	Adults	Numphs	Adults	Both	Nymphs	Adults	Nymphs	Adults	Both
Haller—Dane	Middle	0	2	0	8	66.7	75	27	67	41	5.6
Renk—Dane	Middle	0	22	1	56	61.4	253	64	162	37	37.2
Anderson—Waushara	Middle	1	5	7	68	92.0	31	58	70	67	35.0
Paltzer—Outagamie	Middle	0	62	87	214	79.9	138	84	201	106	27.7
Hodgson—Dane	Early	2	118	395	233	80.9	209	231	144	202	0
Anderson—Waushara	Middle	1	19	365	387	97.3	47	91	182	120	54.3
Wilcox—Waushara	Middle	4	60	559	246	92.0	403	158	73	79	0
Schlough—Dane	Early	69	85	259	218	69.0	181	261	159	185	0
Eagan—Waushara	Early	11	53	464	908	95.3	554	66	804	79	29.8
Olson—Waushara	Early	22	251	657	1433	86.9	436	132	217	91	0
Total		110	677	2794	3771	[2]	2327	1172	2079	1007	[3]

[1] 22.76% *Adelphocoris lineolatus*, 2.26% *A. rapidus*, 74.98% *Lygus oblineatus*.
[2] Nymphs—96.1%; adults—82.1%; both—88.0%.
[3] Nymphs—0; adults—0; both—0.

Table 2.—Leafhopper and mirid control at 14 days in alfalfa fields sprayed with methoxychlor and parathion, Dane County, 1952.

		Numbers of Insects per 50 Sweeps of a 15″ Net[1]							
		Check		Methoxychlor		Per Cent Red.	Parathion		Per Cent Red.
Farm	Cutting	Nymphs	Adults	Nymphs	Adults	Both	Nymphs	Adults	Both
				Leafhoppers					
Hodgson	Late	0	54	1	67	0	2	173	0
Schlough	Late	12	98	43	116	0	3	112	0
Schlough	Middle	269	171	62	97	63.9	6	123	70.7
Schlough	Early	569	346	210	77	68.6	167	142	66.2
Walters	Early	361	227	12	98	81.3	14	164	69.7
Roelke	Early	506	345	15	156	79.9	29	234	69.1
Total		1717	1241	343	611	[2]	221	948	[3]
				Mirids					
Hodgson	Late	12	95	4	109	0	0	114	0
Schlough	Late	59	105	130	111	0	14	206	0
Schlough	Middle	117	200	123	197	0	7	205	33.1
Schlough	Early	176	145	144	185	0	79	276	0
Walters	Early	307	222	616	356	0	99	431	0
Roelke	Early	319	338	270	404	0	240	488	0
Total		990	1105	1287	1362	[4]	439	1720	[5]

[1] 17.33% *Adelphocoris lineolatus*; 3.10% *A. rapidus*; 79.57% *Lygus oblineatus* (Say).
[2] Nymphs 80.6%; adults; 50.8% both 67.8%.
[3] Nymphs 87.1%; adults 23.6%; both 60.5%.
[4] Nymphs 0; adults 0; both 0.
[5] Nymphs 55.66%; adults 0; both 0.

Table 3.—Hay yields in fields sprayed with methoxychlor and parathion, 1952.

Farm—County	Cutting	Methoxychlor	Parathion	Untreated Check
Schlough—Dane	Late	0.75 ton	1+tons	0.50 ton
Schlough—Dane	Middle	0.75 ton	0.75 ton	0.50 ton
Schlough—Dane	Early	1 ton	1+tons	0.25 ton
Water—Dane	Early	134 bales	184 bales	82 bales
Paltzer—Outagamie	Middle	220 bales	Not used	160 bales
Hodgson—Dane	Early	2 tons	Not used	0.75 ton
Eagan—Waushara	Early	1 ton	Not used	0.50 ton
Klesmith[1]—Portage	Middle	2 tons	Not used	1 ton
Increase over check		108%	143%	

[1] Methoxychlor dust at 1.5 lbs./acre—applied 1 month before harvest. Insect control data were not obtained in this field.

Table 4.—Feed analysis[1] of alfalfa hay samples from methoxychlor-treated and check plots, Schlough farm. Sprayed July 5; sampled August 15, 1952.

	Regrowth After Early Cutting		Regrowth After Middle Cutting		Regrowth After Late Cutting	
Feed Component	Treated	Check	Treated	Check	Treated	Check
Protein	18.70	14.90	18.40	16.05	19.10	19.15
Fat	2.20	2.20	2.15	2.20	2.35	2.20
Ash	6.72	5.43	5.92	5.67	6.89	6.32
Moisture	8.40	9.70	9.0	8.90	9.00	8.70
N.F.E.	22.28	31.92	34.83	38.23	26.66	29.63
Fiber	41.70	35.85	29.70	28.95	36.00	34.00
Carbohydrates	63.98	67.77	64.53	67.18	62.66	63.63
Vitamin A (I.U. per pound)	26,700	11,400	26,700	13,350	34,000	30,300

[1] Doty Technical Laboratories, Kansas City, Mo. Acknowledgment is made to E. I. duPont de Nemours & Co. for financing the analysis.

secticide. There is little reason to doubt that even higher hay yields would have resulted if better overall insect protection hae been obtained. It would appear that maximum protection cannot be achieved with one application of methoxychlor or parathion, for these insecticides do not have the characteristic of long-lasting residual effectiveness. The practicality of spraying more than once, or using a clean-up instead of a preventive schedule needs critical evaluation in future research. The wide variations of insect populations in relation to the many different conditions of alfalfa growth should also be considered.

Samples of hay for a chemical feed analysis were taken at the Schlough Farm, Dane Co. On this farm, three stages of regrowth following an early, middle, and late first cutting were adjacent to each other in a single large field. The insecticide and check plots were laid out crosswise to the cuttings. As was anticipated, the check plot of the early cutting showed severe leafhopper yellowing, the middle cutting was moderately yellowed, and the late cutting apparently was little damaged. Reference to data from these plots in table 2 shows that leafhopper populations in early, middle and late cuttings became progressively smaller. Table 3 shows that the yield was greatly increased when the early cutting was treated with insecticide.

A final picture is given when reference is made to the feed analysis data in table 4. The hay quality can be associated with the number of leafhoppers and the control obtained with insecticides. Insect control on alfalfa regrowth after both early and middle cuttings was responsible for about the same degree of hay quality; however, untreated alfalfa following the early cutting was of much lesser quality than that following the middle cutting. No practical quality differences were found in treated and untreated hay regrowth following the late cutting, but insecticides in this cutting management gave clear-cut yield differences. This would suggest that the damage of mirids does not depress quality to the same extent as quantity of forage. It is also likely that the sample from late-cut regrowth had more leaves than other samples. Probably spraying at a later growth stage than stubble would have given better results.

The improvement of hay quality is largely in higher protein and vitamin A. If the better quality of hay is considered in conjunction with an increased tonnage, it is very evident that a large monetary return in feed nutrients can be obtained through the use of insecticides for leafhopper control in second growth alfalfa.

Enzymatic Dehydrochlorination of DDT by Resistant Flies

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The fact that DDT-resistant houseflies are able to dehydrochlorinate DDT (1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane) to DDE (1,1-dichloro-2,2-bis (*p*-chlorophenyl)ethylene) at a faster rate than susceptible houseflies has been reported by Sternburg *et al.* (1950a), Perry & Hoskins (1950), and March & Metcalf (1950). Sternburg & Kearns (1950b), working with a particular strain of DDT-resistant flies (S) obtained from Bruce and Decker (1950), concluded that the abnormal ability of this strain to dehydrochlorinate DDT to DDE as fast as it was absorbed could account for its resistance to the compound. Chadwick (1952) questioned the significance of the dehydrochlorination of DDT as a cause of resistance and suggested that this might simply be the result of flies being able to survive treatment with DDT. The only obvious answer to the question would be to determine if the resistant strains possess a mechanism for the rapid dehydrochlorination of DDT and whether or not this mechanism is absent in susceptible strains.

We have successfully demonstrated the presence of an enzyme system in a strain of DDT-resistant flies (S-strain Bruce and Decker, 1950) which is capable of rapidly dehydrochlorinating DDT to DDE. This same enzyme system is either absent in a susceptible strain (CSMA[1]) or has such a low order of activity that its presence cannot be detected.

The enzyme was isolated as a crude extract from the DDT-resistant flies by grinding the flies in an ice-jacketed Waring blendor containing a 0.9 per cent solution of NaCl in glass distilled water cooled to 0° to 3° C. Six flies were used for each ml. of salt solution. The resulting homogenate was then centrifuged in a refrigerated centrifuge for 10 minutes at 4000 rpm. The supernatant liquid containing the enzyme was decanted through cheesecloth and stored at 0° C. until ready for use.

Extracts from either susceptible or DDT-resistant flies were used experimentally by placing a 2 ml. aliquot of extract in a Warburg reaction flask. The desired pH was obtained by adding 1 ml. of the proper phosphate buffer solution to the contents of the flask The required amount of DDT was then added from an ethanol solution containing 13.2 mg. per ml. At this point any additional materials used under experimental conditions were added to the extract. The flask containing the treated fly extract was then placed on a Warburg manometer and incubated with constant shaking for 1 hour at 37° C. The extract was then transferred to a 125 ml. separatory funnel, extracted with ether, and the ether layer analyzed for DDT and DDE by the method of Schechter *et al.* (1945) as modified by Sternburg & Kearns (1950a).

The most significant conclusion to be drawn from the data presented in tables 1 and 2 is the fact that extracts prepared from DDT-susceptible flies will not dehydrochlorinate DDT even when used under conditions which are presently believed to be near optimum. The enzyme system possessed by DDT-resistant flies will dehydrochlorinate DDT in increasing amounts as the quantity of DDT is increased from 20 to 400 micrograms per 2 ml. of extract, as shown in table II. Thus a crude extract from a single DDT-resistant fly may dehydrochlorinate 5 to 7 micrograms of DDT in one hour under the most favorable conditions presently known.

At the present time the only unquestionable measure of enzymatic detoxification of DDT must be based upon the amount of known non-toxic degradation product which is formed. In this particular case the nontoxic product would appear to be DDE. However, under conditions where the largest amounts of DDE are formed, we find that correspondingly larger amounts of the original quantity of DDT applied cannot be accounted for. This suggests the possibility that DDE is a metabolic intermediate. When we test this assumption by exposing DDE to the dehydrochlorinating enzyme from resistant flies, we

[1] A DDT-susceptible strain of flies distributed by the Chemica Specialty Manufacturers Association to be used for testing chemicals by the Peet-Grady method.

Table 1.—The decomposition of 50 μg. doses of DDT by enzyme extracts of houseflies incubated 1 hour at 37° C. under conditions of different pH and glutathione content. Reaction vessel contents were 2 ml. enzyme extract (6 flies per ml. 0.9% NaCl), 1 ml. phosphate buffer (consisted of mixtures of 0.137 M Na_2HPO_4 and KH_2PO_4), glutathione and DDT.

Source of Enzyme Extract	Mg. Glutathione	pH of Reaction Mixture	μg. DDT Converted to DDE	μg. DDT Unchanged	μg. DDT not Accounted for
3-day old susceptible flies	1.5[1]	7.4	0	51.4	—
	1.5[1]	7.4	0	47.1	—
	1.5	7.4	0	51.4	—
	1.5	7.4	0	50.9	—
	1.5	7.4	0	49.5	—
1-day old resistant flies	1.5	5.5–6.0	5.6	31.6	12.8
	1.5	5.5–6.0	4.2	33.2	12.6
	1.5	6.4	10.0	32.2	7.8
	1.5	6.4	8.7	34.6	6.7
	1.5	7.0	11.1	28.1	10.8
	1.5	7.0	16.0	22.0	12.0
	1.5	7.4	13.2	25.1	11.7
	1.5	7.4	12.3	27.9	9.8
	1.5	9.5	0	39.8	10.2
Resistant flies over 2 weeks old	1.5	6.8	8.7	36.9	4.4
	1.5	6.8	8.8	38.9	2.3
	1.5[2]	6.8	6.0	38.7	5.3
	1.5[2]	6.8	6.7	39.3	4.0
4-day old resistant flies	0	7.4	0	46.3	3.7
	0	7.4	0	46.6	3.3
	1.5	7.4	6.8	38.2	5.0
	1.5	7.4	8.3	40.3	1.4
	3.0	7.4	10.9	38.0	1.1
	3.0	7.4	9.7	40.1	0.2
	6.0	7.4	8.2	37.0	4.8
	6.0	7.4	6.4	42.1	1.5

[1] Enzyme heated for 5 mins. at 60° C.
[2] Run under air. All others run under nitrogen.

find that we can recover substantial quantities of the original compound. As an alternative, it might be assumed that the enzymatic detoxification of DDT by resistant flies could be accomplished by means other than dehydrochlorination. In any event, the detoxifying mechanism seems to be restricted to the DDT-resistant strain because quantitative recovery of DDT from incubated extracts prepared from susceptible flies in an identical manner is consistently possible.

Table 2.—Enzymatic detoxification of DDT by extracts from resistant flies. Two ml. of extract containing enzyme equivalent of 12 flies used in each test. Final volume in reaction flask brought to 3 ml. with 0.137 M phosphate buffer solution. Incubation period 1 hour at 37° C.; pH 7.4; under nitrogen; 1.5 mg. glutathione per flask.

DDT Dosage (μg.)	μg. DDT Metabolized to DDE	μg. DDT Metabolized to unknown	μg. DDT Metabolized Total	μg. DDT Unchanged	Per Cent Metabolism of Applied DDT
25	9.7	0	9.7	15.9	38.8
25	10.3	0	10.3	14.9	41.2
50	10.4	9.9	20.3	29.7	40.7
50	13.1	11.8	24.9	25.1	49.8
50[1]	0			46.4	
50[1]	0			47.9	
100	28.4	15.3	43.7	56.3	43.7
100	24.1	23.3	47.4	52.6	47.4
200	48.8	31.2	80.0	130.0	40.0
200	45.6	30.4	76.0	124.0	38.0
400	84.9	53.6	138.5	261.5	34.6
400	52.4	64.6	117.0	283.0	29.2

[1] Enzyme denatured before use by heating to 70° C. for 5 minutes.

The crude enzyme extract from the DDT-resistant flies will dehydrochlorinate DDT in the presence of air, under at atmosphere of nitrogen, and in the presence of HCN provided that adequate quantities of glutathione are added to the reaction mixture previous to incubation with DDT. We have not established the necessity of glutathione, except that under the conditions in which we now extract and prepare the crude enzyme it would seem to be indispensable for the enzyme to dehydrochlorinate DDT at a rapid rate. Cysteine will not activate the enzyme under the same conditions.

It would appear that the dehydrochlorinating enzyme has an optimum pH of 7.4 or higher, although it can function as low as pH 6. The optimum ratio of glutathione to crude extract would appear to be between 3.0 and 6.0 mg. to 2 ml. of crude extract. The enzyme is inactivated by a temperature of 60° C. or higher.

We are at present attempting the purification of the dehydrochlorinating enzyme from DDT-resistant flies with a view towards studying the kinetics of the reactions involving DDT, glutathione, other sulfhydryl compounds and the possible necessity of coenzymes.

LITERATURE CITED

Bruce, W. N. and G. C. Decker. 1950. Soap 26, 122 and 145.

Chadwick, Leigh E. 1952. The current status of physiological studies on DDT resistance. Amer. Jour. Trop. Med. and Hyg. 1(3): 404–11.

March, R. B. and R. L. Metcalf. 1950. Soap, 26, 121–139.

Perry, A. S. and W. M. Hoskins. 1950. The detoxification of DDT by resistant flies and inhibition of this process by piperonylcyclonene. Science 111: 600–1.

Schechter, M. S., D. B. Soloway, R. A. Hayes, and H. L. Haller. 1945. Colorimetric determination of DDT. Ind. Eng. Chem. Anal. Ed. 17: 704–9.

Sternburg, James, C. W. Kearns, and W. N. Bruce. 1950(a). Absorption and metabolism of DDT by resistant and susceptible houseflies. JOUR. ECON. ENT. 43: 214–19.

Sternburg, James and C. W. Kearns. 1950(b). Degradation of DDT by resistant and susceptible strains of houseflies. Ann. Ent. Soc. Amer. *43:* 444–58.

Sponging Method of Earworm Control in Texas

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To obtain maximum yields of sweet corn in the Lower Rio Grande Valley of Texas it is necessary to make three weekly applications of irrigation water, the first being applied when approximately 5 per cent of the ears are in silk. From 4 to 6 days must elapse after an irrigation before a self-propelled fixed boom sprayer can be used in such fields. Growers, therefore, cannot irrigate their corn in the normal manner, and maintain the proper timing schedule of spray applications which are recommended by Wene & Blanchard (1949), for the control of the corn earworm, *Heliothis armigera* (Hbn.), with fixed boom sprayers.

Since this area has an abundant supply of labor, attempts were made to control the corn earworm by injecting four or five drops of a solution of 1 per cent DDT in mineral oil of 80 to 90 seconds Saybolt viscosity in the silk channels of the ear tips. The control of earworm damage obtained by the injection method was very disappointing. The sponge method was then developed. This consisted of dipping a synthetic rubber sponge, 3.75 inches long, 1.5 inches wide, and 1 inch thick, in a solution of 0.5 per cent DDT in mineral oil of 65 to 90 seconds Saybolt viscosity, and then pressing it on top of the silk of the ear until approximately 1 ml of the solution had run into the silk mass. This treatment was applied once, usually after most of the ears had been fertilized. Growers were obtaining erratic control with this method; therefore, an experiment was designed in 1952 to determine the proper time of sponging corn to obtain maximum earworm control.

MATERIALS AND METHODS.—The experiment was conducted in a field of sweet corn which had been planted to the hybrid, Golden Security. A plot consisted of a single row of corn 40 feet in length. Each timing treatment was replicated four times.

Table 1.—Effectiveness of sponging a solution of 0.5-per cent DDT in mineral oil on the silks of ears for the control of the corn earworm on sweet corn. Weslaco, Texas, 1952.

TIME OF TREATMENT	WORM-FREE EARS	PER CENT OF EARS WITH OIL INJURY	
		1.5 In.	2.5 In.
	(per cent)		
3 and 10 days after silking began	97	17	23
5 and 10 days after silking began	85	30	32
7 days after silking began	87	17	12
9 days after silking began	93	12	8
11 days after silking began	72	3	3
13 days after silking began	60	3	0
Untreated	0	0	0

Two plots each receiving two treatments and four plots receiving a single treatment were included in each replication. Silking records were taken daily. In the first plots receiving two applications, the DDT-oil solution was applied 3 days after silking began in the field and again 10 days later. The other plots receiving two applications were sponged 5 and 10 days after silking began in the field. Plots receiving a single application of the insecticide were treated 7, 9, 11, and 13 days, respectively, after the beginning of silk emergence in the field.

Data on earworm infestation and oil damage to the ears are shown in table 1. They are based on 15 consecutive ears examined from each plot. Worm-free ears did not have any live larvae or signs of larval feeding on the ears. Oil injury prevented development of kernels on the ear tip.

DISCUSSION.—All of the ears in the untreated plots were infested with earworms. Effective earworm control was obtained in those plots which were sponged twice with a solution of 0.5 per cent DDT in mineral oil. One application of the DDT-oil solution applied either 7 or 9 days after silking began in the field also gave effective earworm control. The treatment applied 11 days after silk emergence had begun gave only 72 per cent worm-free ears. At the time of treatment 30 per cent of the ears had corn earworm larvae feeding on the tips, and some of the larvae were in the third or fourth instar, which are difficult to control. Only 60 per cent of the ears were worm-free in those plots which had been treated 13 days after silk emergence began in the field. The data show that a single application of 0.5 per cent DDT

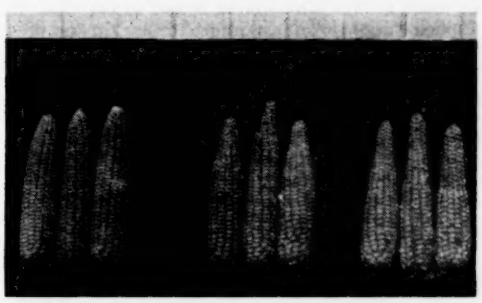

FIG. 1.—Ears on left normal; ears in center injured approximately 1.5 inches on tip by the oil but still marketable; and ears on right severely injured by oil and unmarketable.

in mineral oil sponged on the ear silks 7 or 9 days after silking begins in the field is the proper time for treating the hybrid, Golden Security.

The main objection to using the DDT-oil solution for earworm control is that application to the silks before pollination has taken place will prevent fertilization and the development of the kernels on the ear. In figure 1, the left group of ears was taken from the plot which had been sponged with the DDT-oil solution 11 days after silking had begun in the field. Pollination had been completed and the ears developed normally to the tips. The center group illustrates ears represented in table 1 as having approximately 1.5 inches of oil injury on their tips but which are sold in this area as U. S. No. 1 unclipped ears. Shippers state that 1.5 inches of oil damage does not reduce the value of the ear if it is worm-free. The three ears at the right are representative of those in table 1 having 2.5 inches or more oil damage. This type of ear is unmarketable. The data show that sponging of silks with the DDT-oil solution 5 days after the first silks appeared in the field and again 5 days later injured 32 per cent of the ears. A single sponging 9 days after the ears had begun to silk in the field injured only 8 per cent of the ears severely yet gave 93 per cent worm-free ears. Delaying the sponge application 2 more days reduced the per cent of severely injured ears by 5 per cent but decreased the per cent of worm-free ears by as much as 21 per cent in some cases.

Excellent earworm control could be secured with a minimum of oil injury by going through the field twice and each time sponging only those ears sufficiently mature to escape serious oil injury. The first trip should be made 5 or 6 days after silks have begun to emerge in the field. By that time silks on the older ears will have wilted and begun to turn light brown. Only ears in that condition should be treated. The second trip should be made through the field 4 or 5 days later. Silks on the older ears will be brown by that time and a slight stain remaining from the first application of the oil solution can be observed on the tips of the husks. Only those ears not sponged the first time should be treated. Usually 25 to 40 per cent of the ears will be ready for treatment the first time through the field and 60 to 75 per cent will require treatment on the second trip.

SUMMARY.—Good control of the corn earworm infesting the sweet corn hybrid Golden Security was obtained by dipping a small sponge in a solution of 0.5 per cent DDT in mineral oil and then pressing the sponge on the silk mass of each ear until approximately 1 ml ran into the silk mass. A single treatment applied at one time to all ears in the field should be made 9 days after silking begins in the field. If applied earlier the oil will injure the ear tip and prevent kernel development, and if applied after will not give as good earworm control.

Excellent earworm control should be obtained and oil damage to the ears held to a minimum by making two trips through the field. The first trip should be made 5 or 6 cays after silking begins and the second trip 4 or 5 days later. Only those ears with wilted, light brown silks should be treated each time. Ears treated the first time through should not be retreated.

Caution. Corn plants contaminated with DDT should not be fed to dairy animals or to animals being finished for slaughter. In applying the DDT-oil solution to the silks by the sponge method, the operator should wear rubber gloves to avoid injury to the skin of the hands.

LITERATURE CITED

Barber, George W. 1942. Mineral-oil treatment of sweet corn for earworm control. U. S. Dept. Agri. Circ. 657.

Wene, George P., and R. A. Blanchard. 1949. Control of the corn earworm on sweet corn in the Lower Rio Grande Valley. Texas Agr. Expt. Sta., Prog. Rept. 1154.

Residual Effectiveness of DDT Sprays against Mosquito Breeding in Alaska[1]

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INTRODUCTION.—Larval mosquito collections made at Eielson Air Force Base, Alaska in May, 1951 indicated that mosquito breeding at that installation was still adversely affected by applications of DDT spray applied in previous years. This residual effect of DDT applications at Eielson was first noted in 1949, and again in 1950, and was reported by Travis *et al.* (1950) and Travis *et al.* (1951). Observations reported in this paper represent a continuation of the work started by Travis and his associates of the Alaska Insect Control Project.

INSECTICIDAL DOSAGES AND SAMPLING TECHNIQUE.—A 25-square-mile area at Eielson AFB was sprayed three times in 1948 with a DDT solution as an adulticide. Insecticidal dosage on each occasion was 0.1 lb. of DDT per acre. During the 1949 season the treated area was enlarged to 100-square miles, which received a total of 0.3 lb. of DDT per acre during three applications. One application was as a larvicide, and two as an adulticide at the rate of 0.1 lb. of DDT per acre. The 25-square-mile plot treated in 1948, and located in the center of the 100-square-mile plot, received one additional application of 0.1 lb. of DDT per acre applied to control adults. During the 1950 season this 25-square mile plot received an additional 0.3 lb. per acre in three applications of 0.1 lb. per acre. These treatments gave a total of 1.0 lb. of DDT per acre, accumulated over a three year period, on the centrally located 25-square-mile plot, and 0.3 lb., applied in 1949, on the remainder of the 100-square-mile plot. All applications were made with a C-47 aircraft equipped with wing booms. The DDT solution used each year consisted of 20 per cent DDT in aromatic hydrocarbon solvents.

Residual effectiveness of the treatments was determined in 1949, 1950 and again in 1951 by comparing larval populations in the treated areas with those in adjacent untreated areas. Larval counts were taken by random dipping along transects which were located at half mile intervals along a line running through the center of the plot. Each transect was 0.25 to 0.5 mile long, and none was closer than 0.5 mile to the edge of the plot. A total of eight

[1] This work was conducted under funds allotted by the Dept. of National Defense to the U. S. Dept. of Agriculture, Bureau of Entomology and Plant Quarantine.

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The writers would like to express their appreciation for the technical assistance of enlisted personnel of the 498th Preventive Medicine Company who were on temporary duty with the Alaska Insect Control Project in 1951.

transects was made in the 25-square-mile plot, or 1.0 lb. per acre area, and eight transects were made in the balance of the 100-square-mile plot, or 0.3 lb. per acre area. Total dips along each transect varied from 119 to 266. Two transects were made in adjacent, untreated areas on two sides of the large plot. From 111 to 339 dips were taken on each of the four transects in the untreated area. Eight persons were engaged in the dipping and larval counting activities which were carried out on May 19–20, 1951. At this time the mosquito larval population consisted for the most part of late third or early fourth instars.

RESULTS.—As reported by Travis *et al.* (1951), there were 95 per cent fewer larvae in the 100-square, mile (outer) plot in 1950 than before treatment in 1949. Travis *et al.* (1950, 1951) also reported that the 25-square-mile (inner) plot showed an 86 per cent reduction in numbers of larvae in 1949 following treatment with 0.3 lb. of DDT in 1948, and that this reduction had increased to 89 per cent in 1950 after the area had received an additional 0.4 lb. of DDT per acre in 1949. This last reduction percentage was obtained by comparing 1950 population counts with 1949 pretreatment counts. Persistence of residual effect in both large and small plots is clearly indicated by results of sampling activities in 1951. These results, which are presented in detail in table 1, show percentage reductions of 94.4 and 99.9 for large and small plots respectively compared with population counts made in adjacent untreated areas.

Table 1.—Effects of residual DDT from treatments of larvae and adults in 1948, 1949 and 1950 on populations of mosquito larvae in 1951 at Eielson Air Force Base, Alaska.

Plot	Cumulative DDT Pounds per Acre	Number of Dips	Avg. No. of Larvae per Dip	Percentage Reduction Based on Untreated Areas (1951)
100 sq. mi. (outer)	0.3[1]	1614	0.314	94.4
25 sq. mi. (inner)	1.0[2]	1664	0.006	99.9
Untreated (check)	0	806	5.52	—

[1] Applied in three treatments in 1949.
[2] Applied in ten treatments, each giving 0.1 lb. of DDT per acre. Three treatments in 1948, four in 1949, and three in 1950.

While there was no marked difference in percentage control between the inner and outer plots, there was a very marked difference in the average number of larvae per dip and total larvae in the two plots. A total of 10 larvae, averaging 0.006 per dip, were taken in the inner plot, while 507 larvae, averaging 0.314 per dip, were found in the outer plot. It is interesting to note that 466 of the larvae in the large plot were taken from the outer two transects on each end of the plot. There was a sharp drop in larval counts at a point 1.5 miles from the edge of two sides of the large plot. In general the area was very dry during the 1951 season, which probably accounted for over-all lower larval counts.

SUMMARY.—Larval mosquito collections made at Eielson Air Force Base, Alaska, in May 1951 indicated that mosquito breeding at that base was still adversely affected by applications of DDT applied in previous years. Percentage of reduction in population was determined by comparing population count, in experimental plots with those in adjacent untreated areas. Larval counts made on 19–20 May, 1951 showed a reduction of 94.4 per cent on a 100-square-mile plot which had received 0.3 lb. of DDT per acre, applied in three doses of 0.1 lb. each, in 1949. A smaller 25-square-mile plot which had received a total of 1 lb. of DDT per acre as a result of ten applications of 0.1 lb. each, applied in 1948, 1949 and 1950 showed a reduction of 99.9 per cent. All applications of DDT were made with a C-47 aircraft equipped with a spray boom.

LITERATURE CITED

Travis, B. V., K. H. Applewhite, and Nelson Smith: Control of mosquito larvae in Alaska with DDT, JOUR. ECON. ENT., **43**(3): 350–3, 1950.

Travis, B. V., K. H. Applewhite, J. B. Goldsmith, and G. R. Frith: Additional observations on the control of mosquito larvae in Alaska with DDT (in press), 1951.

Residual Effectiveness of Some Organic Insecticides in Control of Japanese Beetle Larvae

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Since the development of the organic insecticides there has been considerable interest shown in determining the persistence of the effectiveness of some of the materials against Japanese beetle larvae. Schread (1949) reported that toxaphene and benzene hexachloride gave good control of the grubs at the end of 18 months whereas parathion had lost its residual activity in less than 12 months. Fleming & Maines (1950) stated that methoxychlor was only one-tenth as toxic as DDT to grubs in the soil and reported (1951) that pound per pound toxaphene was equal in effectiveness to DDT.

Field tests have been established in Ohio at various times since 1946 using benzene hexachloride, toxaphene, methoxychlor, and parathion at different levels to determine their residual effectiveness in controlling the larvae of the Japanese beetle.

In 1946 an experiment was set up in a park in Cleveland using benzene hexachloride at 0, .25, 2.5, 5.0, and 10.0 pounds of the gamma isomer per acre. All plots consisted of an area 10 by 10 feet and each treatment was replicated five times. The larval population was determined by taking three 0.33 square foot cores of soil from each plot and examining them for grubs. The results of this study are shown in table 1.

Table 1.—Japanese beetle larval population following treatments of different levels of benzene hexachloride applied on September 6, 1946.

Lbs. of Actual Toxicant per Acre	Mean Larval Population per Sq. Ft.				
	Oct. 14 1946	May 28 1947	Oct. 30 1950	Oct. 16 1951	Oct. 16 1952
.25	21.4	11.4	12.8	18.0	10.0
2.5	6.0	1.4	1.8	9.3	6.0
5.0	9.2	4.6	1.2	2.0	2.5
10.0	3.4	.8	.0	1.3	.0
Untreated	18.4	13.0	6.6	20.0	7.5
LSD at 5% level	10.4	4.7	3.7	10.4	6.6

These data show that the .25 pound treatment was never significantly better than the untreated plots during the course of this study. The 2.5 and 5.0 pound levels gave significant reduction in population for six generations of the insect but in the seventh these treatments ceased to produce results that were different from that in the untreated plots. The 10.0 pound rate had reduced the population significantly in five weeks after application and continued to remain very effective through seven generations of the insect.

On October 3, 1947, another experiment was established in the same park area in Cleveland using parathion, toxaphene, methoxychlor, and benzene hexachloride all at different rates. In this test each plot consisted of an area 10 by 50 feet and all treatments were replicated four times. The larval population was determined in the same manner as described in the first experiment. The results of this study are shown in table 2.

Table 2.—Effectiveness of several insecticides in controlling the larvae of the Japanese beetle for different years in plots established in a park area in Cleveland. Treatments were applied October 3, 1947.

Toxicant	Lbs. of Actual Toxicant per Acre	Mean Larval Population per Sq. Ft. May 12 1948	May 18 1949	May 8 1951	May 7 1952
Parathion	5.0	1.8	.3	8.3	26.3
	10.0	.3	.3	2.0	25.0
	20.0	.0	.0	1.8	8.5
Toxaphene	25.0	6.3	.0	.0	.0
	50.0	4.3	.0	.0	.0
	75.0	4.3	.0	.0	.0
Methoxychlor	25.0	11.0	1.5	3.5	5.8
	50.0	13.5	3.3	2.3	5.3
	75.0	10.3	1.0	1.0	1.3
Benzene hexachloride	.25	12.3	2.5	2.0	12.5
	2.5	1.3	.0	.0	1.5
Untreated		21.0	5.0	9.5	28.3
LSD at 5% level		5.4	3.7	3.3	14.4

These data show that throughout the period of the test all levels of toxaphene gave complete control of the grub population. Benzene hexachloride applied at the rate of 2.5 pounds of the gamma isomer per acre was very effective for all of the sampling dates. While the 0.25 pound rate of benzene hexachloride and each of the three levels of methoxychlor gave results that were found to be significantly different from that in the untreated check for every year except 1949, the reduction in the larval population was not great enough to consider these materials effective in the control of Japanese beetle larvae. All levels of parathion were very effective against the larvae that were in the soil at the time of application and also against larvae of the succeeding generation, but it appears that this material lost its residual action very rapidly after being in the soil for three or four generations of the insect. Unfortunately no data are available for the year 1950.

In April of 1948 an experiment was set up in the Youngstown Country Club near Youngstown using toxaphene at 5, 12.5, and 25 pounds of the actual material per acre, parathion at 1, 5, and 25 pounds of the actual material per acre, benzene hexachloride at .25 and 12 pounds of the gamma isomer per acre, and an untreated check. All plots consisted of 100 square feet and each treatment was replicated five times. Population counts were made in the same manner as previously described. The results of this study are shown in table 3.

Table 3.—Effectiveness of different levels of toxaphene, parathion, and benzene hexachloride at Youngstown, Ohio, when applied April 6, 1948.

Toxicant	Lbs. of Actual Toxicant per Acre	Mean Larval Population per Sq. Ft. Oct. 13 1948	Oct. 23 1950	Oct. 10 1951
Toxaphene	5.0	3.0	.0	.3
	12.5	7.8	.0	.0
	25.0	4.4	.0	.3
Parathion	1.0	12.2	15.0	17.5
	5.0	2.6	7.8	21.0
	25.0	2.2	1.6	2.5
Benzene hexachloride	.25	24.4	12.8	22.8
	12.0	.0	.0	.0
Untreated		43.2	11.6	13.0
LSD at 5% level		10.4	7.0	12.2

These data show that the larval populations in all levels of the three insecticides were significantly different from the population in the untreated plots in October of 1948. In 1950 and 1951 effective control was obtained from all of the levels of toxaphene and the 12 pound rate of benzene hexachloride.

In April of 1949 parathion was applied at two different levels to turf in a cemetery in Wellsville, Ohio. The rates used in this experiment were 0, 1, and 5 pounds of the actual material per acre. All plots consisted of 100 square feet and each treatment was replicated four times. Population counts were taken in the same manner as previously described. Results of this study are shown in table 4.

Table 4.—Effectiveness of parathion when applied at two different levels at Wellsville, Ohio, April 11, 1949.

Lbs. of Actual Toxicant per Acre	Mean Larval Population per Sq. Ft. Sept. 30 1949	Oct. 4 1950	Oct. 8 1951	Oct. 2 1952
1.0	.3	3.0	2.3	3.0
5.0	.0	3.0	4.3	1.8
Untreated	17.5	21.0	19.8	10.0
LSD at 5% level	2.9	4.2	9.6	3.9

The data indicated that both of these levels of parathion gave a significant reduction of the grub population in each of the four years in which data were taken.

Summary.—The results of these studies indicate that: (1) benzene hexachloride applied at the rate of 4 ounces of the gamma isomer per acre was ineffective in controlling the larvae of the Japanese beetle, but when it was applied at 2.5, 5.0, 10.0, and 12.0 pounds per acre, the control and the residual effect were significant and became more significant with each increase in the rate; (2) toxaphene applied at rates as low as 5 pounds of the actual material per acre gave significant reduction in grub population for at least three generations of the insect, the higher rates being effective for six generations; (3) parathion was effective in reducing the grub population for one, two, three, or four generations depending on the locality and the concentration used; and (4) all rates of methoxychlor gave significant reduction in larval population for the duration of this study but the material was less effective than other materials used. The data indicate also that the 25 and 50 pound

rates were losing some of their effectiveness after being in the soil for six generations of the insect.

LITERATURE CITED

Fleming, W. E. and W. W. Maines. 1950. Effectiveness of methoxychlor against the Japanese beetle. U. S. Bur. of Ent. and Pl. Quar. Publication E-797.

Fleming, W. E. and W. W. Maines. 1951. Experiments with toxaphene against the Japanese beetle. U. S. Bur. Ent. and Pl. Quar. Publication E-821.

Schread, J. C. 1949. Residual activity of insecticides in control of turf insects. JOUR. ECON. ENT. 42(2): 383–7.

A Spotted Tentiform Leaf Miner Outbreak in California Orchards

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During the 1952 season there occurred a severe outbreak of a lepidopterous leaf miner on the foliage of apple, pear and cherry trees in the orchards of northern California. The greatest amount of damage occurred in the pear orchards of the Sierra Foothills and in the apple orchards of the coastal counties. Though the work of this insect has been noted in these orchards for many years past and it was considered only a minor pest, the increase in population which started in 1951 and reached its peak in 1952 places it temporarily at least as of considerable economic importance. In the heavily infested orchards every leaf on the tree would show from 7 to 15 blotch type mines. By early August the leaves were damaged so severely that they had lost much of their function. No mines were found on the fruit even though eggs were occasionally deposited there.

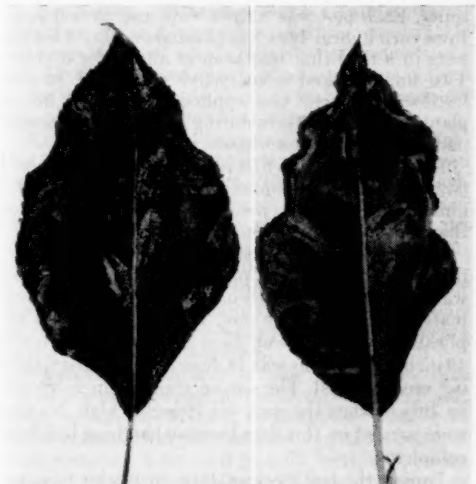

FIG. 1.—Blotch type mines of the spotted tentiform leaf miner on pear foliage.

Damage to the foliage of quince, plum and peach trees in these orchards was of minor importance.

The insect causing this damage has been tentatively identified by Miss Braun as *Lithocolletis crataegella* Clem., the spotted tentiform leaf miner. It is common in eastern United States and has been reported from eastern Canada and the Pacific Northwest.[1]

Biology studies under California conditions were started July, 1952 and will be continued. In many orchards the natural mortality of the leaf miner larvae was very heavy the past season. In one heavily infested pear orchard in the Sierra foothills the natural mortality on August 12 was 11 per cent due to parasitism. From then on it rose rapidly until on November 20 it had reached 98 per cent (55 per cent of which was due to parasitism). Dead larvae were noted within the mines with no indication of parasitism. This may have been due to predator attack as indicated in the Virginia study. Of the several species of parasites which have been reared from the larvae, *Zagrammosoma mirum* Girault and an unidentified species of *Sympiesis* are the predominant species. These are both primary, external feeding parasites of the maturing larva.

Small-Plot Tests of New Insecticides in Control of European Corn Borer, 1950-1951[1]

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The program followed at the European corn borer laboratory of the Bureau of Entomology and Plant Quarantine, at Ankeny, Iowa, for determining the effectiveness of new insecticides against the European corn borer, *Pyrausta nubilalis* (Hbn.), consists of three steps. First, the materials are screened in the laboratory under controlled conditions to select those that show high toxicity to first-instar larvae (Questel 1941). The selected materials are further screened in small field plots (Questel 1943, 1944). Finally, those insecticides that showed considerable promise in the small-plot tests are evaluated under conditions that simulate commercial control before they are recommended for practical use.

Tests in small plots of field corn during the 1950 and 1951 seasons are described herein.

1950 SEASON.—Twenty-one formulations that had been found promising in laboratory tests or effective in small-plot tests, but not yet recommended, and two formulations of DDT were tested against the corn borer in 1950. The treatments in randomized blocks were replicated five times. The plots were 4 rows wide and 20 feet long. A cold-hardy, early-maturing field-corn hybrid, Wisconsin No. 464, was planted in the test plots on May 11.

In the field where the tests were conducted oviposition of the corn borer began on June 13 and continued until after July 3, the peak being between June 22 and 27. In July there were only 9 days with minimum temperatures above 60 F., and the temperature went as low as 49 F. A total of 450 egg

[1] A splendid study of the biology and control of this insect is given in Technical Bulletin 114 of the Virginia Agricultural Experiment Station.

[1] Journal Paper No. J-2063 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 1193.

Table 1.—Results of small-plot tests of insecticides against the European corn borer infesting field corn, 1950.

Insecticide	Formulation	Active Agent per 100 Gallons of Water	Borers in 50 Plants	Borer Reduction
	Per Cent	Pounds	Number	Per Cent
DDT	75 WP	1.0	3	98
	50 WP	1.0	5	96
EPN	27 WP	1.0	3	98
CS-708 (Dilan)	50 WP	1.0	7	94
Ryania+*n*-propyl isome	90+9	3.6+0.36	7	94
Heptachlor	50 WP	1.0	9	93
Dieldrin	25 WP	1.0	10	92
Lindane	25 WP	1.0	11	91
Aldrin	25 WP	1.0	12	90
Rotenone+*n*-propyl isome	2.5+5	0.1+0.2	12	90
CS-708	25 Em	1.0	13	89
Cube powder (rotenone)	5.11	0.2	13	89
Rotenone+*n*-propyl isome	2.5+10 WP	0.1+0.4	14	88
Allethrin	25 WP	1.0	20	84
Methoxychlor+DDT	44+6 WP	0.88+0.12	22	82
Metacide	33 Em	0.33	23	81
Ryania	100	4.0	28	77
Allethrin	100	1.0	28	77
Ryania+sulfoxide	83.5+16.5 WP	3.3+0.66	34	72
Q-137	25 WP	1.0	43	65
Malathon	25 WP	0.5	43	65
Sulfoxide	20 WP	1.0	47	61
Malathon	47.7 Em	0.5	55	55
Untreated check	—	—	121	—

masses per 100 plants were laid in the test field. The borer population in the check plots averaged 2.4 per plant at the time of dissection.

The insecticides were applied to the whorl of the corn plants by hand with a wheelbarrow sprayer, powered with a gasoline engine, in sufficient quantity to reach practically all points where borers usually feed. Alkyl benzene sodium sulfonate,[1] as a wetting agent, was added to the sprays at the rate of 1 part to 2500 parts of solution. Approximately 120 gallons of spray was applied per acre. The first spray was applied on June 30, when the corn was 50 inches high, and the second spray on July 7. All the plants were showing shot-hole injury when the first application was made.

During the last days of July, when a few of the larvae had started to pupate, plant dissections were made and surviving borers counted to determine reductions of the insect caused by the sprays. Five plants were taken from each plot for dissection, the fourth plant from the end on one of the two middle rows and then every other plant until the desired number was obtained. In the same manner five plants from the other middle row were dissected, but starting from the opposite end of the plot. By this method data were obtained on 10 plants in each plot, or a total of 50 in each treatment. The results are shown in table 1.

There were no significant differences in effectiveness between the first 16 formulations listed in table 1 or between the next 7, but all those in the first group were significantly better than the second. All insecticides tested were significantly better than the untreated check. These results were not surprising, since all the materials had shown considerable effectiveness in laboratory tests.

Emulsifiable CS-708 and wettable powders of sulfoxide, rotenone plus *n*-propyl isome, and ryania plus sulfoxide destroyed some leaf tissue in the whorls of the corn plants. Malathon, Q-137, dieldrin, CS-708, and rotenone plus *n*-propyl isome in wettable powders caused some leaf discoloration when sprayed in the whorls of the corn plants. None of the other sprays caused injury.

1951 Season.—Nineteen formulations were compared with one another and with DDT in small-plot tests in 1951. The treatments were replicated five times. Each plot was 3 rows wide and 25 feet long. Iowa corn hybrid 4297 was planted on May 4 for the tests in a field that had been in alfalfa for 3 years. Two hundred and seventy-five pounds of 10-20-0 fertilizer per acre was applied to the soil before planting. Temperatures during May were below normal and precipitation was above normal.

Egg deposition was first recorded on June 12, when two egg masses were found on 20 plants the total number of egg masses per 100 plants was 170, or less than half the number recorded in 1950.

The wheelbarrow sprayer used in 1950 was remodeled to make it self-propelled. As in 1950, spray was applied to the whorls only at the rate of approximately 120 gallons per acre. The first insecticide applications were made on June 29, when the corn was 49 inches high. This was 12 days after the first hatching was observed. The second application was made on July 9, when the corn was 70 inches high. No eggs were present on this date because hatching had been completed.

During the last week of July, just prior to pupation of the corn borer, plant dissections were made to determine reductions in borer populations with the various treatments. Ten plants from the middle row of each plot were dissected, or a total of 50 for each treatment. The check plots averaged approximately

[1] *Ultrawet.*

Table 2.—Results of small-plot tests of insecticides against the European corn borer infesting field corn, 1951.

INSECTICIDE	FORMULATION	ACTIVE AGENT PER 120 GALLONS OF WATER	BORERS IN 50 PLANTS	BORER REDUCTION
	Per Cent	Pounds	Number	Per Cent
DDT	75 WP	1.2	2	96
DDT	0.6 Em	0.3	2	96
Endrin	10 WP	0.48	0	100
EPN	50 Em	0.6	0	100
Heptachlor	25 WP	1.2	0	100
Isodrin	8 WP	0.38	0	100
CS-708 (Dilan)	40 WP	0.96	1	98
Endrin	6.5 Em	0.3	2	96
Lindane	25 WP	0.9	2	96
EPN	25 WP	0.6	2	96
Ryania+*n*-propyl isome	90+9	4.3+0.43	2	96
Metacide	33.4 Em	0.8	2	96
Parathion	15 WP	0.36	3	94
Ryania	100	4.8	3	94
DDT+parathion	25+3 WP	0.6+0.07	3	94
Isodrin	6 Em	0.36	4	92
Allethrin	25 WP	1.2	5	90
Methoxychlor	50 Em	1.2	6	88
Malathon	25 WP	1.2	14	71
Pentachlorophenol	100 Em	0.6	15	69
Methoxychlor	50 WP	1.2	16	67
Untreated check	—	—	48	—

one borer per plant at the time of dissection. The results are shown in table 2.

There was a difference in effectiveness between the first 18 and the next 3 treatments. The latter group was noticeably different, however, from the untreated check. There was no significant difference between the first 18 formulations listed in table 2. Some of the materials—namely, EPN, CS-708, heptachlor, and lindane—reduced populations in both 1950 and 1951. In previous years, however, significant differences did occur between some of these treatments.

Under the procedures used in these tests, pentochlorophenol, endrin, and isodrin in emulsifiable formulations caused severe injury in the whorl. Parathion wettable powder also caused some injury to the whorl. Wettable-powder formulations of malathon, heptachlor, endrin, allethrin, emulsifiable methoxychlor, and ryania plus *n*-propyl isome and a wetting agent caused slight yellowing of some leaves in the whorl. None of the other materials produced any injury to the plants at this time.

On July 12, 3 days following the second application and 13 days after the first, another observation was made. In plots sprayed with Metacide emulsion, corn plants that had shown no injury at the time of the first observation were very much stunted. In addition, pentachlorophenol, endrin, and isodrin emulsions caused severe injury. Malathon and parathion wettable-powder sprays, and methoxychlor emulsion caused slight injury. There was no apparent injury to any of the other plots from treatments during the second application.

SUMMARY.—A number of new insecticides that had shown promise against the European corn borer, *Pyrausta nubilalis* (Hbn.), in laboratory tests were tested in small field plots in 1950 and 1951. Some of these materials were used in both wettable-powder and emulsifiable formulations. They were applied as sprays to the whorl of the corn plant only, at approximately 120 gallons per acre.

In 1950, fourteen of the formulations tested were equal to DDT in effectiveness. In 1951, sixteen formulations compared favorably with DDT. EPN, CS-708, heptachlor, and lindane, because of their favorable performance in both years, offer considerable promise as effective insecticides for use in corn borer control.

LITERATURE CITED

Questel, D. D. 1944, DDT, a promising substitute for ground derris for corn borer control. JOUR. ECON. ENT. **37**(1): 149–50.

Questel, D. D. 1944. Field tests with insecticides to control the European corn borer in early market sweet corn at Toledo, Ohio, in 1943. U. S. Bur. Ent. and Plant Quar. E-609.

Questel, D. D., S. I. Gertler, L. E. Smith, and D. L. Vivian. 1941. Laboratory and field tests of toxicity of some organic compounds to the European corn borer. U. S. Bur. Ent. and Plant Quar. E-557.

Sugar Concentration of Some Massachusetts Honey Plants[1]

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During the past season, the authors made rather extensive investigations of the sugar concentration of some forty honey plants of Massachusetts. The present report, although preliminary in nature, is of value since no other work has been published on this matter in the northeastern United States.

PROCEDURE.—It was necessary to conduct some preliminary tests to determine the best method of taking samples and also to reduce to a minimum errors in observation. At first individual bees were caught, their heads removed and the nectar squeezed from the body. To avoid excess stings we resorted to catching the bees in a cyanide bottle. In connection with this method, it became evident that we should know how rapidly the nectar in the honey sac broke down after the bee had died. We conducted some tests which indicated that there were no significant differences in the sugar concentration of the nectar within 15 minutes after the bee had died. However, tests indicate that a reduction occurred in sugar concentration of the nectar collected thirty minutes after the bee had died. Thus in one series of tests, forty observations, the average sugar concentration was 30 per cent. Nectar recovered from bees within 15 minutes of their death averaged 31.6 per cent. That secured thirty minutes after the death of the bee averaged 28.7 per cent. The extremes in this series were 20 and 36 per cent.

Having established a dependable method of obtaining our samples, we made collections of bees observed to feed on the plants under study. In most cases we secured enough bees to allow us to obtain 10 determinations. In no case had we fewer than five observations. Our procedure after killing the bees was as follows: The head of the bee was cut off. Then the abdomen and thorax were gently squeezed. If the bee had a copious amount of nectar, a large drop would collect at the anterior end of the thorax. This was then placed on the prism of the refractometer and the sugar concentration was observed. All determinations were made by means of a Bausch & Lomb hand model refractometer having a scale of 0–60 per cent. One point of caution should be men-

[1] Contribution from Dept. of Ent., Univ. of Mass. The authors wish to thank the Univ. of Mass. for a research grant to purchase a refractometer.

Table 1

Plant	Sugar Concentration of Nectar in Per Cent			Dates Collected
	Average	Maximum	Minimum	
Dandelion *Taraxacum officinale* Weber	41.8	56	26	May 1–7
Japanese Barberry *Berberis thunbergii* DC	33.9	47	18	May 2–7
Apple (var. Sharon) *Malus* sp.	53.6	63	42	May 9
Cherry (var. Morello) *Prunus cerasus* L.	39.3	47	30.5	May 9
Honeysuckle *Lonicera* sp.	35.9	48	30.5	May 30
Winged Euonymus *Euonymus alata* Reg.	37.4	41	32	May 30
Dutch white clover *Trifolium repens* L.	37	50	27	June 2–27
Bittersweet *Celastrus scandens* L.	36.7	44.5	33	June 5–10
Privet *Ligustrum vulgare* L.	23.5	31	18	June 18–19
Vetch *Vicia cracca* L.	43.5	52	33	June 19–27
Alsike Clover *Trifolium hybridum* L.	39	46.5	26.5	June 19–27
Red Clover *Trifolium pratense* L.	29.5	33	24	June 19–27
Staghorn sumach *Rhus typhina* L.	47.2	53.5	38.5	June 20–26
Yellow sweet clover *Melilotus officinalis* (L.) Lem.	49.3	57	38	June 20–27
European Linden *Tilia europea* L.	56.1	58	54	June 24
White sweet clover *Melilotus alba* Desr.	41.8	48	36	June 24–27
Milkweed *Asclepias syriaca* L.	25.2	30	20	June 26–30
Buckwheat *Fagopyrum esculentum* Moensch	45.1	48.5	41	June 27
Viper's Bugloss *Echium vulgare* L.	41	48	37	June 30
Smooth sumach *Rhus glabra* L.	48.5	58.5	42	July 8–18
Spreading dogbane *Apocynum androsaemifolium* L.	26.6	28	24	July 8
Alfalfa *Medicago sativa* L.	29.3	33	27	July 8
Meadow-sweet *Spiraea salicifolia* L.	23.3	26.5	19	July 22–25
Buttonbush *Cephalanthus occidentalis* L.	35.5	36	35	July 25
Sweet pepper bush *Clethra alnifolia* L.	26.2	34	19.5	July 29–August 4
English Ivy *Hedera helix* L.	26.2	30	17	July 31
Burdock *Arctium minus* Bernh.	30.1	34	20	August 4
Flat top goldenrod *Solidago graminifolia* (L.) Salisb.	29.8	40	22	September 4–9
Hairy goldenrod *Solidago rugosa* Mill	37.9	48	27	September 4–20
Lady's thumb *Polygonum persicaria* L.	45.15	50	42	September 4–9
Winter squash *Cucurbita maxima* Duchesne	29.7	38	18	September 7
Jewelweed	30.8	33.5	26	September 7

Table 1 (continued)

PLANT	SUGAR CONCENTRATION OF NECTAR IN PER CENT			DATES COLLECTED
	Average	Maximum	Minimum	
Impatiens biflora Walt.				
Boneset	21.3	28	21	September 7–8
Eupatorium perfoliatum L.				
Joe Pye Weed	33.3	39	27.5	September 8
Eupatorium purpureum L.				
Japanese Bamboo	31.9	35.5	28.5	September 8
Polygonum cuspidatum Sieb. & Zucc.				
Solidago speciosa Nutt.	27	29	26	September 20
Aster				
Novae-angliae L.	31.6	35	26	September 20
vimineus Lamb.	53.6	55.5	51.5	September 20
acuminatus Mich.	37.3	46	31	September 26
prealtus Poir.	30.0	36	21	September 27

tioned. Bees having small amounts of nectar in their nectar sacs were discarded since data from such samples were found to vary and usually indicated extremely low sugar concentrations.

One further matter requires clarification. We were uncertain as to the necessity for making temperature corrections. The matter was referred to George Vansell, Bur. Ent. & Pl. Quar., Davis, California. Mr. Vansell stated—

"On a practical basis presentation of the raw data with a statement of the conditions is about as far as one can go in taking a series of samples under field conditions."

Our data were obtained, with few exceptions, in the afternoon between 2 and 4 P.M. Data from buckwheat were obtained 10 to 11 A.M. however.

In taking our data, observations of the temperature and relative humidity were also made. Due to the fact that for some plants observations were made over a period of 7 to 10 days, we are not including weather observations in this report. We made preliminary analyses of the relation of temperature and of relative humidity to sugar concentration of the nectar. We could not determine any direct relationship between either temperature or relative humidity and sugar concentration. Whether some multiple correlation exists between temperature, relative humidity and sugar concentration we have not been able to determine.

The data we obtained are presented in Table 1.

From Table 1 it is possible to group the nectar plants in various ways. We decided to set up groups based on average sugar concentrations of nectar. The following limits of concentration were arbitrarily established.

Group I—Plants having average sugar concentration of nectar above 50 per cent.

Apple
European Linden
Aster vimineus

Group II—Plants having average sugar concentrations of 40–50 per cent.

Dandelion
Vetch
Staghorn sumach
Sweet clover
Buckwheat
Vipers' Bugloss
Smooth sumach
Lady's thumb

Group III—Plants having average sugar concentrations of 30 to 40 per cent.

Japanese barberry
Morello cherry
Honeysuckle
Winged euonymus
Dutch white clover
Bittersweet
Alsike clover
Buttonbush
Burdock
Hairy goldenrod
Jewelweed
Joe Pye weed
Japanese bamboo
Aster novae-angliae
Aster acuminatus
Aster prealtus

Group IV—Plants having average sugar concentration below 30 per cent.

Red clover
Milkweed
Privet
Alfalfa
Spreading dogbane
Meadow sweet
Sweet pepperbush
English ivy
Flat-topped goldenrod
Winter squash
Boneset
Solidago speciosa

In general this grouping seems to reflect the attractiveness of the plants to the bees. We observed great numbers of bees on the plants of Group I and II. Bees seemed to be particularly abundant on *Aster vimineus*, smooth sumach, linden, dandelion and sweet clover. A few exceptions can be noted. Thus milkweed which had a relatively low sugar concentration seemed highly attractive to bees. The sugar concentration of sweet pepperbush seems to be low. It is possible that this may be due to the soil conditions where the plants were growing. In general, pepperbush is associated with swampy areas whereas the only plants available for our study grew in moderately dry conditions.

SUMMARY.—The sugar concentrations of some forty honey plants were determined by means of a B & L refractometer. The best technique seemed to be to collect feeding bees in a cyanide bottle, remove their heads and squeeze the nectar from their nectar sacs. It was determined that no significant differences in sugar concentration of the nectar occurred in the body of the bee up to fifteen minutes after the death of the bee. On grouping the plants on the average sugar concentrations of the nectar, it seemed that there was a correlation between sugar concentration and the number of bees present. We were unable to obtain any direct relationship between sugar concentration of nectar and either tem-

perature or relative humidity. It is suspected that there may be a multiple correlation between temperature, relative humidity and sugar concentration.

Rearing Stable Fly for Laboratory Tests

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Early workers (1, 2) successfully reared the stable fly, *Stomoxys calcitrans* (L.), in small numbers to study its life cycle and habits. More recently, Doty (1937) and Eagleson (1943), with fairly complex methods, reared the fly in large numbers for laboratory tests.

The stable fly may also be reared in large numbers by a simplified procedure that has several points in common with the Peet-Grady method (1951) for rearing the housefly. The adults are maintained under the same conditions of relative humidity and temperature. The larvae are reared in battery jars in housefly medium prepared according to the Peet-Grady Method.

Eggs for seeding the jars are procured from a large oviposition cage, which contains 4,000 to 8,000 adults. Cages currently in use measure 30 by 30 by 28 inches, but somewhat smaller cages might suffice. The oviposition cage is provided daily with two dishes of food prepared as follows: a wad of cellucotton about 2.5 inches in diameter is moistened with cool tap water, squeezed nearly dry, and placed in a 4-inch porcelain evaporating dish; bovine blood is poured over the cellucotton nearly sufficient to fill the dish and provide a relatively large free surface of blood surrounding the cellucotton. This method of feeding is similar to that reported by Woodbury (1943).

The bovine blood is obtained weekly from a local meat-packing plant. Sodium citrate solution (50 g. sodium citrate per liter of water) is introduced to the container at the rate of 64 ml. per liter of blood prior to collection of the blood. The citrated blood is refrigerated at 40° F. as a further aid to preservation.

The adults begin to lay eggs in the food dishes when the level of the blood drops. The spent food dishes are removed from the oviposition cage when fresh ones are introduced, and the eggs are transferred with a wash bottle into a beaker. They are cleaned by decanting with tap water and are seeded onto the surface of the larval medium at the rate of 0.3 ml. of eggs for each jar. The jars are covered with muslin, placed on shelves in the rearing room, and let undisturbed during larval development.

The larvae do not work the top of the medium, and a hard crust forms. When the crust is gently removed on the fourteenth day after seeding, the pupae are found concentrated near the edges of the jar. They are loosened with a spatula, transferred to beakers, and allowed to emerge in a holding cage. The adults are then used in tests or transferred as needed to the oviposition cage to maintain the breeding population.

The life cycle of the stable fly, reared in the manner described, is shown in table 1. Other pertinent rearing data are shown in table 2.

Table 1.—Life cycle of the stable fly.
(Averages from 19 laboratory cultures)

EVENT	DAYS AFTER SEEDING EGGS
Appearance of first pupae	9
Emergence of first adults	14
Peak emergence	17
First egg laying	21

Table 2.— Miscellaneous rearing data.
(Averages from 19 laboratory cultures)

Yield of pupae per jar	2240
Pupal weight, g./100	1.26
Adult weight, g./100	1.4
Emergence from pupae, %	86
Eggs developed into adults, %	57

LITERATURE CITED

Newstead, R. 1906. On the life history of *Stomoxys calcitrans* (L.). Jour. Econ. Biology **1**: 157–66.

Mitzmain, M. B. 1913. The bionomics of *Stomoxys calcitrans* (L.); A preliminary account. Philippine Jour. Sci. **8B**: 29–48.

Doty, A. E. 1937. Convenient method of rearing the stable fly. JOUR. ECON. ENT. **30**(2): 367–9.

Eagleson, C., in Campbell and Moulton. 1943. Laboratory procedures in the studies of the chemical control of insects. Publication No. 20, American Association for the Advancement of Science, Washington, D. C.: pp. 77–8.

Blue-Book and Catalog Edition of Soap and Sanitary Chemicals, 24th ed., 1951. New York, McNair-Dorland Company: pp. 237–40.

Woodbury, E. N., in Campbell & Moulton. 1943. Laboratory procedures in the studies of the chemical control of insects. Publication No. 20, American Association for the Advancement of Science, Washington, D. C.: pp. 60–73.

Scientific Names of the Body and Head Lice

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The extensive literature on these human lice has reflected confusion and lack of uniformity concerning the status and the names of the two forms. There seems now, however, to be almost complete agreement that the body louse and the head louse are best treated as subspecies of a single species. There is also no longer any doubt concerning the correct names for these two environmental segregates of *Pediculus humanus* L. Dr. G. H. E. Hopkins, of the British Museum (Natural History) has recently (Entomologist **85**: 90, 1952) made it perfectly clear that, since the first restriction of the name *humanus* L. was its application by Latreille, 1803, to the body louse, it must also be used for that form in the subspecific sense. Moreover, the name *capitis*, which was the first name to be used in a restricted sense for the head louse, must be applied to that form. Accordingly, the correct name for the body louse is *Pediculus humanus humanus* L. and the correct name for the head louse is *Pediculus humanus capitis* Deg.

A Tactile Ovipositional Stimulus to Culture *Macrocentrus ancylivorus* on an Unnatural Host

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Various ovipositional stimuli have been noted among braconid parasites attacking lepidopterous larvae. With some of these parasites the olfactory stimuli play a dominant role, as with *Apanteles aristoteliae* Vier., which may track its host larvae, *Argyrotaenia citrana* (Fern.), over long distances by their fresh spoor. With other braconid parasites the olfactory response apparently plays little or no part in stimulating oviposition. Thus *Macrocentrus ancylivorus* Rohwer completely ignores Its potato tuberworm host, *Gnorimoschema operculella* (Zell.), when the larva is crawling outside its burrow. It was observed by the author, however, that *M. ancylivorus* could be incited to probe with its ovipositor through frass piles of the potato tuberworm in the absence of larval hosts in the burrows beneath, and that ovipositional probing was also stimulated by cloth which had been impregnated with honey. Daniel (1932) recorded that larval frass piles as well as webbing incited oviposition by *M. ancylivorus* in one of its natural field hosts, the strawberry leaf roller, *Ancylis comptana fragariae* (W. & R.).

The above facts suggested that the primary stimulus for oviposition by *Macrocentrus ancylivorus* was a tactile response to certain textures, and that if such were the case some of the more cosmopolitan cereal moths might serve as laboratory hosts for insectary production of the parasite if they could be induced to deposit surface frass piles on a cereal medium. A medium consisting, by weight, of 12 parts wheat middlings, 8 parts mill-run bran, 10 parts water, 10 parts honey, and 0.1 part of a commercial mold preventive product[1] combined the requirements for favorable development of the Indian-meal moth, *Plodia interpunctella* (Hbn.). When this medium was compressed to produce a smooth surface, it provided the desired surface for frass piles. *M. ancylivorus* adults readily searched this habitat, and successfully parasitized the young larvae in their burrows. Adult parasites emerged approximately 23 days after oviposition.

Eggs of *Plodia* were obtained by confining the adult moths in jars covered with fine-mesh wire or plastic screen through which the loose eggs could be shaken. The cereal medium was packed into the bottom of jars or petri dishes to a depth of 0.5 inch or more to produce a smooth surface. Puncturing the medium surface with small holes insured uniform distribution of larval burrows. Twenty to 30 *Plodia* eggs were scattered per square inch of medium surface. They hatched in 3 to 4 days at 80° F. Stinging of larvae approximately 2 ml. in length by *Macrocentrus ancylivorus* proceeded most readily when the parasites were closely confined to the surface of the medium.

LITERATURE CITED

Daniel, Derrill McC. 1932. *Macrocentrus ancylivorus* Rohwer, a polyembrionic braconid parasite of the oriental fruit moth. N. Y. State Agr. Expt. Sta. Tech. Bul. **187**: 1–101.

[1] Mycoban; a propietary product of E. I. duPont de Nemours & Co. (Inc).

Use of a Virus Disease to Control European Pine Sawfly[1]

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In 1950 F. T. Bird (1950), of the Canadian Department of Agriculture, successfully disseminated a virus disease of the European pine sawfly, *Neodiprion sertifer* (Geoff.), in heavily infested pine pine plantations near Strathroy, Ontario. The disease, which was discovered in Europe, was sent to Canada in 1949, where it was extremely virulent against this pest. A stock suspension of virus was prepared from 2000 virus-killed larvae in 2000 cc. of water. Various dilutions of this suspension were sprayed on infested trees with a hand-operated sprayer. A dilution of 100 cc. to 3 imperial gallons of water effected complete control, and a dilution of only 0.1 cc. to 3 imperial gallons resulted in an infectious spray. In 1951 sufficient stock solution for 100 gallons of dilute spray was sent to the United States. It was used by the Bureau of Entomology and Plant Quarantine in cooperation with the New Jersey Department of Agriculture to treat a small area of infested pine with a knapsack sprayer. In 1952 a somewhat larger area in New Jersey was treated from an airplane and a small area in Illinois was treated from the ground.

GROUND SPRAYING IN NEW JERSEY.—Two plantations at Stephens State Park in Hackettstown, N. J., were used for experimental work in 1951. The two areas are about 200 yards apart and are separated by a State highway. Both are well stocked with red and scotch pine from 6 to 10 feet tall. Both were heavily infested with *Neodiprion sertifer*. Five red pines selected in each area for intensive observation had an average of 22 egg clusters (about 1000 eggs) per tree. Cloth trays were placed under these trees to catch any larvae that fell to the ground. Spraying was confined to one area; the other was used as a check.

On May 1 one-half acre was sprayed with the stock solution diluted, according to Dr. Bird's recommendations, to approximately 250 million polyhedra per U. S. gallon. Sixty gallons of spray were applied with a knap-sack sprayer equipped with a fine spray nozzle and the foliage was well drenched.

At the time the spray was applied about 90 per cent of the *sertifer* eggs had hatched. On May 9 there was a heavy fall of dead larvae and they continued to fall for about two weeks. Complete larval mortality occurred on the five trees under which the cloth trays had been placed. A total of 4846 dead larvae were recovered. In so far as could be ascertained, results were equally good over the entire half-acre. Mortality on the check area was very low. During the same period only 49 dead larvae were recovered under the five trees in the untreated area, and an examination of 32 of these larvae proved that none died from the virus disease. In contrast, out of 292 larvae examined from the sprayed area, 285 died from the virus disease.

On May 14, when most of the *sertifer* larvae were about three-fourths grown, another half-acre was treated. The same concentration of spray was used, and equally good results were obtained. Two or

[1] This paper was presented at a meeting of the American Association of Economic Entomologists, at Philadelphia, Pa., December 15–18, 1952.

three trees, however, were obviously missed. The larvae on these trees completed development normally in spite of their being close to diseased larvae on nearby trees.

A concentrated suspension of virus polyhedra can be obtained simply by placing diseased larvae in water and waiting for them to disintegrate. A large number of larvae, therefore, were collected and a supply of polyhedra was obtained for use in 1952.

No spraying was done at Stephens State Park in 1952, but cloth trays were again placed under selected trees—five in the area sprayed in 1951 and five in the check area. A few diseased larvae were found in the check area. The limit of spread from trees treated in 1951 was about 300 yards. In the sprayed area few larvae were found except on trees that had been missed. On these trees some diseased larvae were found. A few were also found in adjacent parts of the plantation.

GROUND SPRAYING IN ILLINOIS.–In 1952 D. M. Benjamin and A. T. Drooz, of the Bureau, and J. D. Larson, W. Ashby, and L. Louck, of the Illinois Division of Forestry, treated three small areas on the Henderson State Forest in Illinois with a virus spray made from diseased *sertifer*. The virus was applied in a concentration of about 2 billion polyhedra per U. S. gallon with knapsack sprayers equipped with nozzles adjusted to produce a fine mist. The trees were treated quickly by spraying while walking down the rows. Inclement weather prevailed, in that an occasional drizzle occurred, but observations made by the State Forester's office indicated 82-, 96-, and 100-per cent control on the treated areas, where 131 larval colonies were under observation.

AIRPLANE SPRAYING IN NEW JERSEY.—In 1952 the virus from diseased *sertifer* was successfully applied from an airplane. An 18.6-acre block of heavily infested red and scotch pine near Blairstown, N. J., was treated on May 14. A water suspension of polyhedral bodies was used at about 10 times the concentration used for ground sprays in New Jersey—*i.e.*, about 2.5 billion polyhedra per gallon. One pint of glycerol was added per 3.5 gallons of spray. It was believed that the addition of glycerol might help prevent evaporation, and preliminary tests had shown that glycerol did not affect the potency of the spray. The area was flown twice and 55 gallons of spray were released.[2] However, there was a slight breeze, and it is believed that the plot was treated at the rate of about 2 gallons per acre. Complete or almost complete control was effected. A total of 2602 dead, diseased larvae were recovered from eight cloth trays scattered throughout the plot, and no living cocoons were found under sampled trees. A further search for living *sertifer* will be made next spring. The work proved without doubt that the disease can be satisfactorily distributed by airplane.

SUMMARY.—Canadian entomologists successfully disseminated a virus disease of the European pine sawfly, *Neodiprion sertifer* (Geoff.) in Ontario in 1950. The disease was made available for use in New Jersey in 1951. Complete control of the pest was effected on a small area sprayed with a knapsack sprayer. In 1952 excellent control was obtained in Illinois when the disease was applied with ground equipment, and in New Jersey when applied from an airplane.

LITERATURE CITED

Bird, F. T. 1950. The dissemination and propagation of a virus disease affecting the European pine sawfly (*Neodiprion sertifer* (Geoff.)). Canada Sci. Serv. Div. Ent. Forest Insect. Bi-mon. Prog. Rpt. 6(5): 2–3.

[2] J. Miller, of the Bureau of Entomology and Plant Quarantine, Beltsville, Md. piloted the plane.

On the Systemic Action of Systox on Cotton

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Reports regarding the effectiveness of Systox [0,0-diethyl-0-2-(ethylmercapto)-ethyl thiophosphate] on spider mites on cotton, have been highly variable. It is hoped that the following observations and experiments will shed some light on these divergent reports.

During the 1951 season a number of experiments were conducted in the Tulare and Five Points areas of California using a 1 per cent Systox dust for the control of both *Tetranychus bimaculatus* Harvey and *T. pacificus* McGregor. The control of both species was highly effective, but there was considerable question as to how much of the control was actually due to a systemic action. In one case mites were placed on newly developed foliage one week after treatment with no sign of any control. An interesting sidelight was observed in these experiments. There was up to a 60 per cent mortality of *T. bimaculatus* eggs using 40 pounds of 1 per cent dust per acre. The mortality of pacific mite eggs was not as pronounced in these experiments.

In 1952 the experiments using Systox on cotton were continued at Visalia, California. This time a 21.2 per cent emulsion was used for all the experiments. The resultant spider mite control was excellent, but again there was a question as to how much of this action was systemic and how much might be due to contact or fumigation. In an attempt to learn more about the action of Systox on cotton, the following experiments were conducted on cotton plants which had attained most of their seasonal growth.

The first experiment consisted of mixing 10, 20 and 40 cc. of the Systox emulsion in 2 gallons of water and immersing the top leaves of cotton plants in the mixture. The plants were kept bent over until dry in order to prevent dripping onto the lower leaves. There was very little evidence of any kill on the lower leaves, indicating little or no downward translocation in the plants.

The second experiment consisted of spraying the lower lateral branches while keeping the top of the plant covered with a paper bag. In this case there was some mortality of the mites on the upper parts of the plants, but the kill was far short of the complete control that is often observed when the entire plant is sprayed.

The third experiment consisted of placing a tub containing 15 cc. of Systox emulsion in 2 gallons of water under a cotton plant with the plant bent over the tub. A screen was placed over the tub to prevent any leaves from coming within 6 inches of the solution. In this case all the mites above the tub and many of those on the leaves extending beyond the rim of the tub were dead within 24 hours. This indicates that there is a very definite fumigating action of Systox which is apparently of considerable importance.

The fourth test consisted of placing drops of Systox, mixed 15 cc. to the gallon, on the upper surfaces of a number of leaves. Within 20 minutes

the mites on the underside of the treated leaves appeared to become agitated, and by the next day there was a complete kill of the active forms. The mites on the adjacent leaves were apparently not affected.

The last test was designed to determine whether there was a systemic action obtained from ground applications. Forty cc. of Systox emulsion was mixed in 2 gallons of water and poured along 10 linear feet of row, then covered with earth. Twenty four hours later there was very nearly a 100 per cent control of the mites. To eliminate any possibility of a fumigating action having been responsible, a tin trough full of soil was buried along side of a row of plants and the same type of application was made by pouring the Systox into the soil within the trough. This time there was some kill of the mites on the lower leaves, but none on the upper leaves.

SUMMARY.—At present it appears that the systemic action of Systox on cotton is highly effective from material picked up by the roots, and by material dispersed within single leaves, but the downward movement in the stems and petioles of the leaves is almost completely absent. The systemic action of Systox is assisted greatly by an effective contact and fumigating action. The fumigating action is so great that at times it appears to be the major factor in the kill of spider mites by Systox.

Tinea fuscipunctella Associated with *Tyroglyphus lintneri*

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In January 1936, our attention was called to a moldy can of wheat from which small moths were escaping through rusted holes. Within were hundreds or moths and larvae, as well as two spiders, and numerous mites and thief ants, the latter attacking the moth larvae by seizing them with their mandibles. An occasional dead larva could be found. Not recognizing the moth as one of the common pests of stored grain, specimens were submitted to the U. S. National Museum with the resultant determination by Mr. Busch as *Tinea fuscipunctella* Haworth. Forbes (1923) lists the larvae of this moth as breeding in the trash in pigeons' nests and similar refuse. He says that it is one of the commonest of the *Tineas* and flies in May and June, and again in August. The distribution was then listed as Europe and Labrador to Pennsylvania. Storage near the can of wheat of a nest of the red-eyed vireo containing cocoons similar to those of the moth indicated the possible source of infestation. Adults of *T. fuscipunctella* have since been reared from the nest of a brown thresher at Champaign, Illinois.

The discovery of this infested wheat indicated the possibility of a new pest of stored grain previously unreported. In several attempts to establish cultures on a new supply of clean wheat, we never succeeded in developing another generation when only mated females or their eggs were transferred, even though the wheat was moistened with water. Success was attained only when it was noted that in the old culture individual larvae were often surrounded by a ball-like mass of mites with no apparent injury to the larvae. Thereafter, all that was necessary was to inoculate each new culture with moisture and mites and release some mated females, with the result that forthwith another complete generation was produced. Unfortunately, due to loss of our cultures, complete rearing records were not obtained.

Submission of specimens of the mites to the U. S. National Museum provided the identification of *Tyroglyphus lintneri* Osb. by Dr. H. E. Ewing, who stated that the mite is very common in grain, stored food, and in many other situations. Whether there is any actual interrelation between *T. lintneri* Osb. and *Tinea fuscipunctella* is a question that someone may care to investigate further. The larvae seemed to be unable to feed upon the whole kernels of wheat. The possibility is suggested that the mites were feeding upon the wheat and the larvae in turn feeding upon the mite excrement or other refuse since they did not develop upon the wheat alone.

LITERATURE CITED

Forbes, William T. M. 1923. Lepidoptera of New York and neighboring states. Memoir 68, Cornell Univ., Agr. Expt. Sta., 126.

Termite Treatment with One Per Cent Solution of Chlordane[1]

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This is the fifth yearly report on the toxicity of soil surrounding a house in Urbana, Ill. treated for termites in early September 1947. The first test of soil toxicity was in early November 1948 (Shelford 1949). Some indication of a preference for certain shrubs was found in 1948, but further investigation with planted wood in a heavily infested area did not add any information of value (Shelford 1950).

Soil has been removed from near the foundation and tested with termite workers in five successive years. A good deal of difficulty was experienced in keeping the control termites alive and in apparent good health. These experiences suggested that to live more than 7 to 10 days, the insects must have food. This was provided in the 1952 tests by running a double set of tests, one with wood in which they had been working in both experiment and control, and another set without wood. The wood in the toxic soil delayed the paralysis 2 to 3 hours. Four controls were run. One of the controls without wood died in 10 days; the other lived 4 weeks. Whether this was due to some small pieces of plant stem in the soil was not ascertainable. The controls with wood were still normal when the experiment was ended after 4 weeks. One of the controls was in sterilized soil (Shelford 1952a). There was less growth of fungus than in earlier years, but some did appear on the bodies of termites that died. Moisture was maintained in the containers by spraying with a very small medical atomizer (Shelford 1952b).

The matter of containers, size, shape and method of sealing was given more attention. The normal habits of the insects appear to consist of random soil tunneling which finally ends in one or more established tunnels probably leading to the wood when present, or to the surface in other cultures. In general, the insects appear to survive better when the soil is tightly packed, so that the tunneling can go

[1] Chlordane was supplied by the Velsicol Corporation, the emulsifier by the Atlas Powder Co., and the emulsion was prepared by W. N. Bruce of the Natural History Survey. The chlordane was pumped into the soil surrounding the foundation by the Illini Pest Control and Service Corporation, courtesy of W. K. Delaplane, Jr.

on, but it should not be more than 0.25 to 0.125 inch deep or it interferes with observation. The 22 cc. homeopathic vials abandoned after two general tests in which they were used, were found to be satisfactory when soil 0.1875 inch deep in the center was packed into one side, and the vial laid on its side. The tunneling took place and the workers could be seen either in the tunnels or on the surface.

About 60 termites were divided among three large mouthed pint fruit jars, one as a control with sterilized soil, another control with unsterilized garden soil, and the third with toxic soil. All were supplied with wood. The jars were sealed with the usual rubber gaskets. The workers died in the toxic soil in 2 days, or half the usual time, and the controls were dead in a week. Some experiences indicate that sealing of containers may be detrimental. The successful experiments were opened daily.

The 5 cc. stender dishes (Shelford 1952a) were abandoned and 25 cc. dishes of the same type capacity were substituted. Soil was packed tight into the bottoms to a depth of 0.1875 inch. The ground glass covers were sealed with glycerine. These were entirely satisfactory for use with 5 to 15 workers.

The behavior of the workers in the various stages of paralysis has been described in the earlier papers. There was no evidence of reduced toxicity at the end of 5 years. As was pointed out earlier, the suspension of chlordane was not uniformly introduced into the soil surrounding the foundation where samples were taken. One sample from a point where the chlordane would have to reach the surface laterally and from below showed paralysis after 4 days, and died after 5 days. One 3 inches deeper at the same spot gave paralysis in 36 hours and death in 2 days.

Foundation soil was collected from a point where it was nearly dry. It was diluted with garden soil to make the following series based on a total of 6 parts of the toxic soil placed first.

No. of parts . .	6–0	3–3	2–4	1–5
Time to leg movement only	20 hrs.	24 hrs.	48 hrs.	48 hrs. plus (began at night)

In most of the experiments body movement ceased after 20 to 36 hours.

The dilution results suggest that a large dilution of the chlordane will be required to render the soil around the foundation non-toxic. This may not be dilution in the sense that essentially all the particles are loaded with one-sixth of one per cent chlordane (last column) instead of 1 per cent. Mixing the two soils dry and then moistening the mixture may have merely reduced the number of toxic particles to a large extent without an equal amount of transfer of the chlordane from the toxic to the non-toxic particles. However, it appears that the soil will remain toxic for several more years.

LITERATURE CITED

Shelford, V. E. 1949. Termite treatment with aqueous solution of chlordane. JOUR. ECON. ENT. **42**(3): 541.

Shelford, V. E. 1950. Termite treatment with aqueous solution of chlordane. JOUR. ECON. ENT. **43**(1): 107.

Shelford, V. E. 1952a. Termite Treatment with aqueous solution of chlordane, JOUR. ECON. ENT. **45**(1): 127.

Shelford, V. E. 1952b. Termite treatment with aqueous solution of chlordane, JOUR. ECON. ENT. **45**(3): 544.

DDT-Resistance and Its Inheritance in the House Fly[1]

C. MARY HARRISON,[2] *London School of Hygiene and Tropical Medicine*

Resistance to DDT and other insecticides in the housefly has arisen in a number of widely separated parts of the world, but the problem of fly control has assumed greatest importance in regions where the climate is particularly favorable for rapid fly breeding. In some Mediterranean countries and parts of the United States attempts to control fly populations with a wide range of different insecticides have failed. Although resistant flies occur in many parts of Northern Europe, the problem of fly control is rarely an urgent one. This is true at least for Great Britain where flies may be prevalent in a particularly warm summer, but not in numbers of the same order as in parts of the United States. Comparatively few field observations have been made on resistant flies in Great Britain, but because of the world wide importance of this problem, laboratory studies are in progress.

When resistance to DDT in the housefly was first discovered, there was a tendency to assume that resistance might be due to a comparatively simple mechanism, possibly the conversion of DDT to a non-toxic metabolite brought by an enzyme mechanism. Experiments over the past two years, however, have shown that although such a mechanism may play a major part (March & Metcalf 1950), it is by no means the complete answer to the problem.

Experiments at the London School of Hygiene and Tropical Medicine have shown that DDT-resistance in housefly strains is not necessarily of precisely the same nature (Busvine 1951). Two strains which were examined had very different properties. One DDT-resistant strain was obtained through the kindness of Professor Missiroli from Italy in 1948. The degree of resistance of this strain was low when first obtained, but was readily increased by selection with DDT in the laboratory. The other DDT-resistant strain came from Sardinia in 1950 after both DDT and chlordane had been used on the island. A third strain, also obtained from Italy, was non-resistant.

If measured doses of DDT are applied from a microsyringe in the back of the thorax of flies of these two strains, a similar result is obtained. The dose of DDT in mineral oil necessary to give a 50 per cent kill 24 hours after treatment is approximately 16 times greater in both the Italian and Sardinian resistant strains than with normal flies. Although a resistance of 16 times does not appear to be great, Busvine (1951) has shown that the apparent resistance is dependent on the type of solvent used in applying the DDT. On the basis of the lethal dose 50, the Sardinian strain proved to be 16 times more resistant than the normal flies when DDT was applied in mineral oil, but 300 times more resistant than normal flies when DDT was applied in precisely the same manner, using acetone as the solvent. Resistance to kill by an applied dose of DDT is similar then in both the Italian and Sardinian strains of flies. If, however, flies of these same strains are allowed to walk over a glass surface which has been treated with 10 mg. DDT per sq. ft. and the time for paralysis to occur is noted, a very different result is

[1] Investigation paper Eastern Branch, November 1952.

[2] At Rutgers University, New Brunswick, N. J., September to December 1952, on a Fulbright Travel Scholarship.

obtained. Sardinian flies were paralyzed almost as quickly as normal flies, whereas flies of the Italian strain were resistant to paralysis or "knockdown." If the Sardinian flies were removed from the treated surface and placed in clean cages, a large proportion were able to recover completely.

These results suggest that either the mechanism responsible for resistance takes more time to be brought into play in Sardinian flies than in the Italian strain, or alternatively that there are two or more mechanisms contributing to resistance in the Italian strain, which may not be present in every resistant strain of flies.

Dr. Busvine (1951) examined both the Italian and Sardinian flies for resistance to other insecticides as well as DDT. The Italian strain was resistant to DDT and not to other chlorinated hydrocarbons, but slightly resistant to pyrethrins. The Sardinian flies were resistant not only to DDT, but lso to chlordane, dieldrin, aldrin, gamma BHC and toxaphene.

The intensity of resistance of fly strains has been observed to decrease in many cases where the insects are bred in the laboratory without coming into contact with insecticide. There is variation between different strains in the rate of loss of resistance, but it is usually slow and it is clear that resistance is passed on from one generation to the next. There is considerable confusion, however, as to the precise mode of this inheritance. Evidence from mass mating experiments carried out in the United States has led to the conclusion that resistance is controlled by multiple factors (Bruce & Decker 1950). The suggestion that resistance is indeed no simple problem is borne out by crossing experiments between resistant and normal flies. Individual flies of the Italian DDT-resistant strain were crossed with non-resistant flies from Italy. The "knockdown" test was used to determine the degree of DDT-resistance in these experiments. It is possible by this method to measure the resistance to paralysis of every fly in a sample, and this factor is particularly important when dealing with the progeny of a single pair of flies. An examination of the non-resistant Italian strain shows that the population is very homogeneous, all flies being "knocked down" within one hour. The population of the Italian resistant strain on the other hand is heterogeneous, some flies being paralyzed quite rapidly while others are highly resistant. Only those flies having a high degree of resistance to "knockdown" from this strain were used in crossing experiments.

Pupae taken from the non-resistant and Italian resistant cultures were placed in separate tubes and on emergence the flies were paired. After eggs were obtained, the parents were tested for resistance and the progeny of those crosses in which the resistant parent was not highly resistant were discarded. Again the F_1 generation flies were mated and eggs obtained before the resistance of the adults was determined.

Flies of the F_1 generation of a cross, either of a resistant female by a non-resistant male or vice versa, although not quite as susceptible to DDT as the non-resistant strain were readily paralyzed. The slight deviation from the "knockdown" curve shown by the normal fly strain could not be explained by hybrid vigor since F_1 progeny of a cross between two non-resistant flies did not show any increased resistance to paralysis. The population of the F_2 generation was clearly segregated into two sections. One portion of the population succumbed readily to DDT while the rest of the population was more resistant. Since no flies of the normal strain were able to withstand the DDT for longer than 60 minutes, this point was chosen as the criterion of susceptibility. The percentage of non-resistant flies in the F_2 generation fluctuates from case to case, but a statistical examination shows that they are all close to 75 per cent. This suggests that so far as resistance to "knockdown" is concerned, a simple Mendelian inheritance is involved, non-resistance being dominant although dominance may not be quite complete. This interpretation of the results is further justified by backcrossing experiments between flies of the F_1 generation and flies of the resistant parental stock. If single factor inheritance is involved, such a cross should give progeny 50 per cent of which are resistant and 50 per cent non-resistant, and this type of result was obtained. A cross between an F_1 hybrid fly and a fly of the normal parental stock gave susceptible progeny which is further evidence of single factor inheritance with non-resistance being dominant. It should be pointed out that these experiments relate only to "knockdown" with one particular fly strain which was resistant to "knockdown."

The property of resistance to paralysis, since it is not present in all DDT-resistant strains, may have little or no connection with resistance to kill when a dose of DDT is applied to the back of the thorax. Preliminary experiments in which DDT is applied to flies derived from crosses between DDT-resistant and normal flies suggest that this may be so. Flies of the Italian resistant strain were crossed with normal flies and the progeny tested by the applied dose technique. The major difficulty in this type of test is to obtain sufficient progeny from a single pair of flies to determine the resistance adequately. Four such crossing experiments have yielded F_1 progeny which are very homogeneous, the resistance being approximately intermediate between that of the parent strains. The F_2 generation flies were considerably more heterogeneous, some being as susceptible as those of the resistant strain, with large numbers intermediate in resistance. These results, although far from conclusive, are indicative of multiple factor inheritance. It would appear that resistance to kill by an applied dose and resistance to paralysis with DDT are inherited in different ways at least in this particular strain. There was no evidence in any of these crossing experiments of cytoplasmic inheritance, or that sex chromosomes play any part, since reciprocal crosses gave similar results (Crow 1952).

The theory that there is more than one factor concerned in resistance in the Italian resistant strain is borne out again by an examination of the detoxification of DDT to DDE. Winteringham (1952) working with the same strains of flies found that both the Italian and Sardinian resistant flies converted DDT to DDE, but DDT is metabolized only very slowly and this mechanism does not therefore account for resistance to "knockdown" in the Italian resistant strain. Busvine (1951) found a correlation between the resistance of flies of the Sardinian strain to various DDT analogues and the ease of dehydrochlorination of these analogues in vitro, but this correlation did not exist with the Italian resistant strain which was capable of withstanding compounds difficult to dehydrochlorinate in vitro more readily. Winteringham (1952) found the Italian resistant strain was resistant to 1:1-bis (4-chlorophenyl) 2-nitro propane, a compound with a DDT-like

structure which could not be dehydrochlorinated, whereas the Sardinian strain succumbed as readily as a normal strain. Busvine (1953) obtained a similar result when working with dianisylneopentane. This compound has a somewhat similar structure to DDT, but contains no chlorine and hence cannot be dehydrochlorinated.

From a consideration of all these results, it would appear that the Italian resistant strain of flies has the ability to detoxify DDT to DDE but also has some additional mechanism which is not present in the Sardinian resistant strain. It is unlikely that the differences between these two strains in "knock-down" and kill can be explained by differences in the penetration of the cuticle, since the paralyzing effect of DDT was exhibited earlier by the Sardinian flies than the Italian ones after injection as well as after application of the insecticide (Busvine 1951).

The resistance of a population can be readily increased by selection in the laboratory, and it is quite well established that selection plays an important part in the development of resistant strains in the field. Selection of individuals most resistant to DDT, however, also involves an unavoidable selection for other characters. Many differences between resistant and normal lines of flies may be accounted for in this way. Since characters which have little or no bearing on resistance may have been selected, the final determination of the factor or factors responsible for resistance to DDT upon an insect may prove exceptionally difficult.

Literature Cited

Bruce, W. D. and C. C. Decker. 1950. Soap **26**(3): 145.
Busvine, J. R. 1951. Nature. Aug. 4, 193–8.
Busvine, J. R. 1953. Nature. Jan. 7, 118–22.
Crow, J. 1952. Conference on insecticide resistance and insect physiology. Nat. Acad. Sci. publ. **219:** 72–8.
March, R. B. and R. L. Metcalf. 1950. Soap **26** (7): 12.
Winteringham, F. P. W. 1952. Conference on insecticide resistance and insect physiology. Nat. Acad. Sci. pub. **219:** 61–6.

Ectoparasites from Mammals at Camp Lejeune, North Carolina[1]

Ted Tibbetts, Lt. MSC, *U. S. Navy*

The following species and host list of ectoparasites from mammals are based on material collected during the past year (1952), by the Epidemic Disease Control Unit No. 3, Camp Lejeune, North Carolina.

The material was collected to determine the possible disease vectors present in this area.

With a few exceptions the small mammals were taken alive in the field and brought back to the laboratory for examination.

The survey for ectoparasites is still being carried on and many new records for the state may be added in the near future.

ACARINA

Haemogamasus hirsutus Berlese
Virginia opossum

Liponyssus bacoti Hirst
Norway rat

Echinolaelaps echidninus (Berlese)
Eastern cotton rat

Myobia sp.
Virginia opossum

Trombicula splendens Ewing
Virginia opossum
Gray squirrel
Eastern red fox

Trombicula (E) alfreddugesi (Oudemans)
Eastern raccoon

Euschongasta peromysci Ewing
Eastern cottontail

Amblyomma americanum Linn.
Man
Dog
Virginia deer
Eastern raccoon
Eastern red fox
Virginia opossum
Gray squirrel
Fox squirrel

Dermacentor variables (Say)
Eastern raccoon
Virginia opossum

Haemaphysalis leporis-palustris Packard
Eastern cottontail

Ixodes scapularis Say
Man

Rhipicephalis sanquineus Lat.
Dog

ANOPLURA

Phthirus pubis Leach
Man

MALLOPHAGA[2]

Neohaematopinus sciurinus (Mjob)
Gray squirrel

Neotrichodectes mephitidis (Pack)
Eastern skunk

SIPHONAPTERA

Echidnophaga gallinacea (Westwood)
Cat
Virginia opossum

Cediopsylla simplex (Baker)
Eastern cottontail
Carolina marsh rabbit
Eastern red fox

Ctenocephalides canis (Curtis)
Dog
Virginia opossum
Eastern red fox
Cat

Ctenocephalides felis (Bouche)
Cat

Orchopeas howardii (Baker)
Fox squirrel
Gray squirrel

Opisodasys pseudarctomys (Baker)
Fox Squirrel

Stenoponia americana (Baker)
Eastern cotton rat

[1] This work is not to be construed as necessarily reflecting the views of the Navy Department.
[2] The Mallophaga were determined by Dr. C. F. W. Muesebeck, of the U. S. Bureau of Entomology and Plant Quarantine.

CAPTAN—A Coined Name for the Fungicidal Chemical N-trichloromethylthio tetrahydrophthalimide.

The word "*captan*" has been selected as a coined name for the fungicidal chemical N-trichloromethylthio tetrahydrophthalimide and approved September 25, 1952 by the Interdepartmental Committee on Pest Control. The name has also been approved by the American Phytopathological Society, and the American Chemical Society is agreeable to its use. *Captan* formerly was designated as SR-406 and ORTHOCIDE.

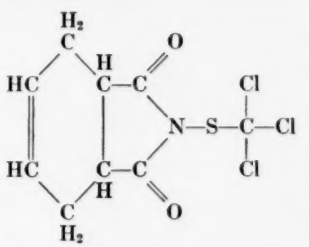
Captan is in the process of being registered by California Spray-Chemical Corporation as a trademark in the United States and in important foreign countries. The California Spray-Chemical Corporation has taken steps to transfer the name to the supplementary list in the Trade-Mark Division from the list where it originally was registered for application as a trade-mark. The name "*captan*" therefore is available for use as a common name for designating this chemical.

The name "captan" applies to the pure chemical and a technical grade shall indicate the percentage of captan present.

PHYSICAL AND CHEMICAL PROPERTIES.

Empirical Formula: $C_9H_8O_2NSCl_3$

Structural Formula:



Data on the pure substance and the technical product are tabulated below.

	Pure	*Technical*
Color	white	yellow
Form	crystalline	amorphous
Odor	slight	pungent
Melting Point	172° C.	158–164° C.
Specific gravity	1.5	1.5

SOLUBILITY.—Practically insoluble in water; partially soluble in organic solvents such as acetone, benzene and toluene; soluble in chlorinated solvents such as ethylene dichloride, chloroform, etc., to the extent of 0.5 per cent.

COMPATIBILITY.—Captan reacts chemically with strong alkaline materials but is stable in neutral or slightly acid solutions. The fungicidal activity has been shown to be reduced by the addition of hydrated lime or other alkaline additives. No indication of reduced fungicidal efficiency or increased plant toxicity due to chemical or physical incompatibility was evident when "captan" was tested in mixtures containing lead arsenate, summer oil, DDT, TDE, parathion, tetraethyl pyrophosphate, chlordane, toxaphene, ferbam and phenyl mercuric acetate and other similar materials.

PHYTOTOXICITY.—When employed in concentrations used for plant disease control "captan" is said to be non-injurious to a wide variety of plants, including the apple, peach, cherry, grape, celery, tomato, potato, carrot, carnation and rose. In addition, it has been tested for plant tolerance on beans peppers, eggplants, onions, cabbage, avocados and nursery greenhouse crops.

FUNGICIDAL PROPERTIES.—Field experiments and commercial usage with "captan" have shown its usefulness in the control of apple scab, Brook's fruit spot, sooty blotch, fly-specking, black rot and cedar rust of apples; brown rot and scab of peaches; cherry leaf spot and brown rot of cherries; black rot of grapes; Cercospora leaf spot of celery; late blight, early blight, gray leaf spot and bacterial leaf spot of tomatoes; early and late blight of potatoes; downy mildew and anthracnose of cucurbits; combination of Alternaria and Cercospora leaf spot of carrots; Septoria leaf spot of chrysanthemums; Alternaria leaf spot of carnations; Rhizoctonia in the soil; black spot of roses; large brown leaf patch of turf; and as a seed-treating chemical. It is also useful in paints, plastics, leather, fabrics, etc., as a fungicide. It has also shown value in the treatment of fungus organisms attacking man and animals.

TOXICITY TO ANIMALS.—In studies made by a qualified laboratory of industrial toxicology, it has been found that "*captan*" when employed in the form of a wettable powder, has a low order of toxicity to warm blooded animals. When given in a single oral dose to rats the LD-50 was found to be greater than 15 grams per kilogram. Intraperitoneal administration of N-trichloromethylthio tetrahydrophthalimide resulted in an LD-50 in the range of 50 to 100 milligrams per kilogram. This would indicate that the material is about 100 times as toxic by intraperitoneal as by oral route. The application of concentrated suspensions of the material to skin surfaces has failed to produce any toxic symptoms, which would tend to show the substance is not absorbed by the skin. While it has not caused skin irritation when applied to human skin exposed to air, it has caused some irritation when used undiluted where skin applications were sealed from air.

When present in concentrations recommended for spraying, "captan" produced no noticeable irritation of the eyes.

Toxicity studies completed to date have been used as a means of determining short-term or acute effects. No information is yet available on the possible chronic effects of prolonged exposure, but such tests are in progress.

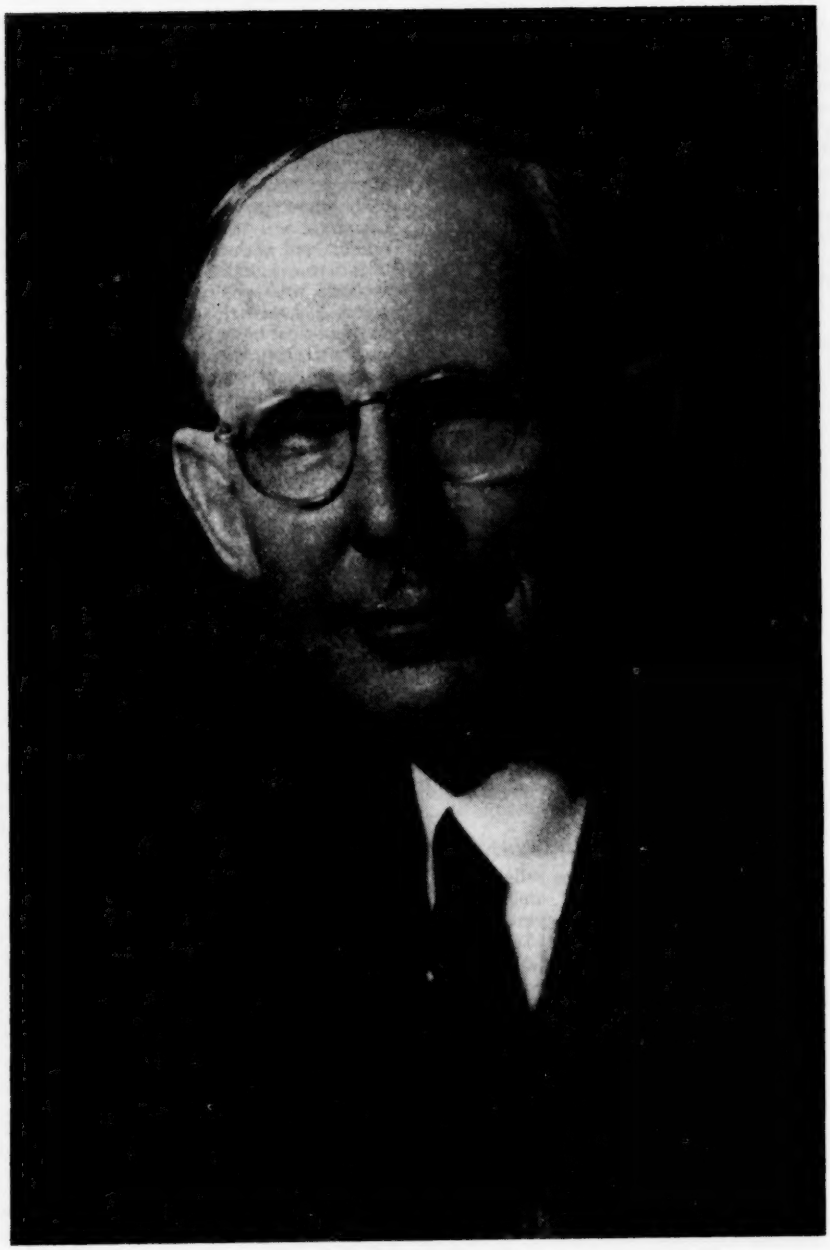
Inhalation studies indicate that "captan" in concentrated powder form may be irritating to bronchial and lung tissue. It therefore is recommended that a espirator be used to prevent such inhalation when working with concentrated material.

Because of the low degree of oral toxicity and the low concentrations used, "captan" should cause no spray residue problem.

ANALYTICAL METHODS.—Analytical methods have been developed for determining "captan" in the technical product and in the wettable powder. Copies of these methods can be obtained from California Spray-Chemical Corporation, Lucas and Ortho Way, Richmond, California.

SOURCE OF DATA.—This release was prepared on the basis of data from the California Spray-Chemical Corporation which assumes responsibility for its contents.

H. L. HALLER, *Chairman*
S. W. SIMMONS, *Secretary*



William Randolph Walton
(1873-1952)

OBITUARY

William Randolph Walton
(1873-1952)

Our Association sustained a serious loss on October 20 last, in the passing of one of its earliest and most highly valued members, William Randolph Walton, at his home in Hyattsville, Maryland, after a long, varied and extremely useful career.

He was born in Brooklyn, New York, September 23, 1873, and was the second son of First Lieut. Walter Walton, U. S. Marines, and wife Susan (MacArdell) Walton, and was of English-Scotch ancestry. His early education was obtained in the public schools of Middletown, New York, and, while still young he became deeply interested in the study of the out-of-doors, in plants and animals, and in birds and insects. As time went on, he also developed considerable manual, mechanical and mathematical proficiency, as well as noteworthy skill in drawing. Upon the death of his father, the lad, then age 17, began as telegraph operator, and thereafter from 1890 until 1906 he was successively rodman, chainman, draftsman, and assistant engineer for various railroads and engineering firms. During that period he also was student for a time at the Stevenson School of Art in Pittsburgh, Pennsylvania, where in 1905 and 1906 he was its prize student. From 1906 to 1910 he served as entomological artist, botanist, photographer, model maker, entomological specialist and research worker for the Pennsylvania State Division of Economic Zoology at Harrisburg. He had already specialized in Dipterology, the families Syrphidae, Asilidae and Tachinidae, and had published a number of papers on their taxonomy. In 1909 he published "An Illustrated Glossary of Chaetotaxy and Anatomical Terms Used in Describing Diptera," upon preparation of which he had bestowed enormous toil and pains, and which ultimately attained a wide usefulness among technical workers.

The beginning of his 33 years of service with the United States Department of Agriculture was on October 1, 1910, with his appointment at age 37 in the then Bureau of Entomology under the leadership of Professor F. M. Webster, in charge of the Division of Cereal and Forage Insect Investigations. There he served in a wide variety of duties as artist, technical office assistant, and general utility helper in the Washington office of that Division. His taxonomic studies too were continued and in 1913–14 he made investigations and published on certain parasitic and predaceous Diptera in northeastern New Mexico. Following the death of Professor Webster, and, after a brief interval as acting in charge, he served in leadership of the Division from March 1, 1917, to September 1, 1923. Since the scope of the work of the Division, particularly its emphasis on development of control, of all the more outstanding pests of cereal and forage crops, is already widely known, and the results are already matters of published record elsewhere, it is not deemed necessary to particularize them in this brief sketch. He continued to serve the Division until his retirement from Government service, at age 70, on September 1, 1943. Thereafter he was made USDA Collaborator for life. His valuable insect collection already had been presented so the U. S. National Museum some time before.

A close observer and a prolific writer, his published works on entomological and related subjects from 1897 to 1947 inclusive, comprised 139 titles. In addition to those already mentioned, they comprised economic treatment of a large number of the more important pests of staple crops, and results of studies on earthworms as pests and otherwise. An enthusiastic fisherman, he also contributed from time to time numerous articles on fresh-water fishing and related subjects for various outdoor periodicals under the nom de plume of "Bill Notlaw" (the name "Walton" spelled backwards). These had wide circulation. During the years following his retirement, he spent much time and toil in preparation of a comprehensive general index, as yet unpublished, to the first forty volumes of the Proceedings of the Entomological Society of Washington.

The versatility of his talents and activities were indicated in his spare time interests in books, pictures, music, photography, radio, television and the like, and his remarkable skill in manual craftsmanship. The latter was many times manifested by the ease with which he could either paint a picture, draw up a house plan, repair a time-piece, make a radio set, or electro copper or silver plate some article of jewelry, or do a wide variety of things like these in his home studio-laboratory-workshop and then share them with his friends.

His memberships and fellowships in scientific and other organizations at various periods of his life included such as the Cosmos Club (1925–1932); the American Association for the Advancement of Science (fellow); the American Association of Economic Entomologists; the Entomological Society of America; the Entomological Society of Washington, (president two years; editor sixteen years); the New York Entomological Society; the Entomological Society of France; the Agriculture History Society; the Biological Society of Washington and Pi Gamma Mu.

He was also a member of St. Jerome's Roman Catholic Church of Hyattsville, its Holy Name Society and its Parish Study Club.

Mr. Walton was married June 9, 1904 to Mary Agnes Becher of Pittsburgh, Pennsylvania, who with one daughter, four sons and eleven grandchildren have survived him.

Possessed of sterling integrity, high ideals, great goodness of heart, and a genuine liking for his fellow beings, these were attributes that drew to him over the years a wide circle of friends from widely separated walks of life, who shared his interests, and who were inspired by and enjoyed association with him. During his long period of administrative work a considerable number of those who are today's foremost workers in economic entomology had the good fortune to have served at one time or another under the stimulus of his leadership. And these also join with his other friends in highest regard for him, and in cherishing for his memory deep and lasting veneration, loyalty and affection.

W. A. Baker
J. S. Wade

PROCEEDINGS OF THE TWENTY-FOURTH ANNUAL MEETING

Eastern Branch, American Association of Economic Entomologists

Lord Baltimore Hotel, Baltimore, Maryland November 24 and 25, 1952

The Twenty-Fourth Annual Meeting of the Eastern Branch, American Association of Economic Entomologists, was called to order by the Chairman, Floyd F. Smith, at 9:30 A.M. November 24 in the Lord Baltimore Hotel, Baltimore, Maryland. During the following day and a half the Chairman and the Vice-Chairman, P. J. Chapman, presided over the presentation and discussion of some 33 papers. The afternoon of the second day was devoted to a symposium, "Insect Resistance to Chemicals," the Moderator being Dr. F. C. Bishopp of the Bureau of Entomology and Plant Quarantine. Guest speakers on this program were Dr. R. W. Fay, U. S. Public Health Service, Dr. F. H. Babers, Bureau of Entomology and Plant Quarantine, and Dr. C. Mary Harrison, School of Hygiene and Tropical Medicine, University of London. Preceding the symposium, Dr. E. F. Knipling, President of the Parent Association, extended greetings and an invitation to attend the National meeting which was to be held in Philadelphia in mid-December.

At the preliminary business meeting during the first day, the report of the Secretary-Treasurer was read and the financial statement presented was referred to the Auditing Committee. Chairman Smith appointed the following committees:

Nominations: L. P. Ditman, T. Walter Reed and J. O. Pepper, *Chairman.*
Auditing: E. N. Woodbury and F. L. Gambrell.
Resolutions: S. S. Sharp, E. H. Siegler and Neely Turner, *Chairman*

Report of the Secretary-Treasurer

Notices of the Twenty-fourth Annual Meeting to be held in Baltimore in November were mailed out to 816 members and eligible members residing in the Eastern Branch territory in late September. Similar notices were sent to 160 members of the Entomological Society of America residing in the area since the two societies had voted to combine and form a single national organization. Invitations to present paper titles brought forth a gratifying response in that 33 paper titles were sent in. These were arranged in a program covering 3 half-days of the 2-day session and which was printed and mailed out to approximately 1000 individuals a week before the meeting.

At the final business session on November 25, 1952, the following committee reports were submitted and passed without any dissenting votes.

FINANCIAL STATEMENT

Balance on hand, November 13, 1951			$4,552.24
Receipts			
Dues for 1951–52—November 1951 meeting		$408.00	
Dues for 1952–53		168.00	576.00
Total Receipts			$5,128.24
Purchased on April 12, 1952			
Four (4) U. S. Treasury Bonds[1]			$3,965.55
Balance			$1,162.69
Disbursements			
King Cole Projection Service		$ 80.00	
Payment to Secretary-Treasurer 1952		200.00	
Expenses of Secretary-Treasurer 23rd Annual Meeting		24.57	
Clerical Expenses		56.90	
Stamped Envelopes	$ 25.00		
	19.88		
	35.27	80.15	
Printer			
Eastern Branch Program—1951 meeting	$ 39.00		
Letterheads	9.90	48.90	
Double Payment of Dues		$ 14.00	
Total Disbursements			$ 504.52

Balance on hand, November 18, 1952			$ 658.17
Distributed as follows:			
Check Account, First National Bank of Cranbury, N. J.	$677.07		
Less Outstanding Check—11-3-52	56.90	$620.17	
Cash on hand in office		38.00	$ 658.17

[1] On March 14, 1952, a balance of $4,602.67 at the Union National Bank and Trust Company, Mount Holly, N. J. was transferred to the First National Bank of Cranbury, N. J. In order to receive a fair return on the Eastern Branch funds it was decided on April 21, 1952 to purchase four (4) $1,000.00. U. S. Treasury Bonds, 2½%, due June of 1967-72 for $3,965.55. After the purchase of these bonds there was a deposit in the checking account at the First National Bank of Cranbury of $637.12.

BYRLEY F. DRIGGERS,
Secretary-Treasurer

REPORT OF THE RESOLUTIONS COMMITTEE

(1) Whereas, the Lord Baltimore Hotel has extended its full cooperation in housing this 24th meeting of the Eastern Branch of the A.A.E.E., be it resolved that the Secretary of the Eastern Branch convey our appreciation to the Management of the Lord Baltimore Hotel.

(2) Whereas, the committee on local arrangements has considered many details and provided suitable services for a successful meeting, be it resolved that we extend our thanks to A. E. Badertscher.

(3) Whereas, the Program Committee has made a special study of the needs of Eastern Branch meetings, and has reported its findings, be it resolved that we express our thanks to them for their study of this very difficult matter.

(4) Whereas, the deaths of J. L. King and T. A. Dobbins have left us with deep feelings of loss, be it resolved that the Secretary of the Eastern Branch of the A.A.E.E. convey to their families our sincere sympathies and condolences in their loss.

S. S. SHARP
E. H. SIEGLER
NEELY TURNER, *Chairman*

REPORT OF THE AUDITING COMMITTEE

Your Auditing Committee has examined the financial statement, books and records of the Secretary-Treasurer (Dr. B. F. Driggers) and find them correct and in good order.

FOSTER L. GAMBRELL
ELTON N. WOODBURY

REPORT OF THE NOMINATING COMMITTEE

Your Committee proposes the following names to serve as officers of the Eastern Branch in 1953:

For *Chairman:* Dr. P. J. CHAPMAN
For *Vice-Chairman:* Dr. H. G. WALKER
T. W. REED
L. P. DITMAN
J. O. PEPPER, *Chairman*

REPORT OF THE COMMITTEE ON PROGRAM CHANGES

At the last annual meeting of the Eastern Branch held in New York City on November 15 and 16, 1951, Dr. J. G. Matthysse introduced at the final business session the following motion which was adopted: "I move that a committee be appointed to investigate the desirability of changing part or all of the Eastern Branch program from a paper reading session to topic discussion type sessions." In accordance with this motion, Chairman Floyd F. Smith appointed a committee to study this proposal.

This committee undertook the assignment and devised a questionnaire which was mailed to each person who attended the Branch meeting or paid dues to the Branch during the last five years. This questionnaire was sent to 427 individuals and 157 (approx. 35 per cent) were returned.

The following items appeared in the questionnaire and the vote is recorded in the space provided for marking the ballot:

1. (59) I prefer to see the same type program as presented in past years continued by the Eastern Branch.
2. (42) I would prefer a topic discussion program without formal papers.
3. (7) I prefer a one session program even if one night session is required.
4. (21) I prefer that the program be run in two or more concurrent subject matter sessions.

In addition to those ballots receiving one choice, four were returned with check marks on both items 1 and 3, 2 were returned with check marks on items 1 and 4, ten were returned with check marks on items 2 and 3, ten were returned with check marks on items 2 and 4, and two ballots were unmarked.

On the basis of the questionnaire, your committee feels that there is no justification for a change in the type of program.

Respectfully submitted,
H. H. RICHARDSON
H. H. SCHWARDT
H. G. WALKER
E. H. WHEELER
P. B. PEPPER, *Chairman*

At the conclusion of the Symposium on Insect Resistance to Chemicals on Tuesday afternoon, the meeting was adjourned with the announcement that the Twenty-Fifth Annual Meeting would be held in Philadelphia in November, 1953.

MEMBERS AND GUESTS REGISTERED AT THE TWENTY-FOURTH ANNUAL MEETING, EASTERN BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS, NOVEMBER 24 AND 25, 1952

Abrams, Louis J.
Adams, Lloyd E.
Alexander, C. C.
Allen, H. W.
Allen, W. C.
Alpert, M.
App, Bernard A.
Asquith, Dean
Atcheson, Walter C.

Babers, Frank H.
Back, Richard C.
Badertscher, A. Edison
Baillie, E. C.
Baker, Howard
Barker, John S.
Barron, F. Ray
Barrow, Mancefield
Bartley, Clayton E.
Bender, Edward K.
Berry, Robert C.
Billings, Samuel C.
Bilyeu, Jack F.
Bishopp, F. C.
Bissell, Theo. L.
Bixby, A. F.
Blickle, R. L.
Bodenstein, Otelia
Boote, R. O.
Boyd, William
Brandes, Gordon A.
Brunn, L. K.
Bunn, Ralph W.
Burch, Ernest A.
Burrage, R. H.
Busbey, Ruth L.

Calsetta, Douglas
Cantelo, William
Chapman, P. J.
Cleary, Thomas F.
Cochran, A. Boyd
Cohill, Roger W.
Connell, Walter A.
Connolly, Patrick J.
Corliss, J. M.
Cory, Ernest N.
Cox, James A.
Cunliffe, Fred

Darley, Merrill M.
Davis, Louis G.
Dean, R. W.
Dent, Russell G.
Dickinson, Berton C.
Dietz, Harry F.
Dimond, John B.
Ditman, L. P.
Driggers, Byrley F.
Dunn, Henry A.

Ehrlich, Alexander
Ezzat, Yehia Makmoud

Fairchild, H. E.
Fales, John H.
Fay Richard Wm.
Filmer, Robert S.
Fleming, Walter E.
Fletcher, Fred W.
Friedman, Saul Z.

Galloway, A. L.
Gambrell, F. L.
Gerber, Chas. F.
Gerberg, Eugene J.
Gesell, S. G.
Gilbert, Engel
Ginsburg, Joseph M.
Givens, Kenneth T.
Glass, Edward H.
Graham, Castillo
Granett, Philip
Greenwald, Margaret
Gyrisco, Geo. G.

Haeussler, G. J.
Hamilton, Clyde C.
Hammer, O. H.
Hanley, Joseph F.
Harcourt, D. G.
Harding Jr., Wallace C.
Harris, C. S.
Harris, Max F.
Harrison, C. Mary
Hart, William G.
Hartley, R. O.
Hastings, S. J.
Haubein, Albert H.
Haviland, Elizabeth E.
Haynes, Harry L.
Heal, Ralph E.
Herron, John C.
Hill, Charles C.
Hill, Clarence H.
Hodges, Raymond
Hoffman, Clarence H.
Holden, K. R.
Holway, Richard T.
Hope, Donald E.
Hornstein, Irwin
Horsfall, J. L.
Hovey, Charles L.
Howe, R. G.
Howe, W. L.
Huffington, Jesse
Hutchins, Francis E.
Hutchinson, Martin T.

Incho, Harry H.

James, Joe E.
James, W. Scott
Janjua, Nazeer A.
Jarnagin, Wm.
Jennings, C. C.
Jobbins, Daniel M.
Johanson, F. D.
Johnson, Warren T.
Jones, M. P.
Jordon, W. B.

Kerr, T. W.
Kirkpatrick, Dale H.
Kriner, Ray R.
Kring, James B.

Langford, Geo. S.
LaPlante, Albert A.
Larson, N. P.
Lathrop, F. H.
Latta, Randall
Lee, Robert M.
Lembach, John V.
Leonard, M. D.
Lindaberry, Harold
Lloyd, George W.
Long, Larry
Lovell, Byron

MacCreary, Donald
McAlister, Jr., L. C.
McCalley, Russell W.
McConnell, H. S.
McIntire, Robert R.
McPherson, Jr., James B.
McGovran, E. R.
Maddrey, J. B.
Magner, J. M.
Mallis, Arnold
Manzelli, M. A.
Mason, Horatio C.
Menusan, Jr., H.
Meyer, Martin T.
Mills, Jr., H. O.
Mitchell, Robert T.
Mitlin, Norman
Murray, James E.

Nash, Kenneth B.
Nelson, R. H.
Nelson, Russell W.
Nolan, Kenneth G.

Pass, Herbert A.
Pechuman, L. L.
Pepper, Bailey B.
Pepper, J. O.
Piquett, Price G.
Pontoriero, Pasquale L.
Poos, F. W.
Porter, B. A.
Pratt, Jr., John J.

Ratledge, Edward L.
Rawlins, W. A.
Reed, T. W.
Reichard, M. D.
Richmond, Roy G.
Ritchie, Thomas M.
Roan, Cliff
Roark, R. C.
Roth, Roger W.

Sacktor, B.
Schread, John C.
Schroeder, H. O.
Schumaker, George
Scoggins, John K.
Shands, W. A.
Sharp, Robert D.
Sharp, S. S.
Shockley, Wilfred
Siegler, E. H.
Smith, Edward H.
Smith, Floyd F.
Spear, Philip J.
Spyhalski, Edward J.
Steiner, Harold M.
Stevens, Lewis F.
Stokes, R. L.
Stoneleigh, D. R.
Swenson, K. G.

Taft, Jr., Harrie M.
Taschenberg, E. F.
Tempone, Frank
Thompson, Friar
Thompson, Hugh E.
Tischler, Nathaniel
Tousey, R. G.
Tsao, Ching Hsi
Turner, Neely

Udine, E. J.
Ullrich, Donald E.

Vance, Arlo M.
Vandenberg, George B.
Vannote, Robert L.

Wadley, F. M.
Walker, H. G.
Walton, Margaret
Washburn, Lloyd
Wert, R. W.
Wheeler, E. H.
Whitcomb, W. D.
William, Michele
Wilson, Billy Ray
Wisecup, C. B.
Woodbury, E. N.

Zappe, M. P.
Zukel, John

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

REPORT OF THE SECTION OF TEACHING

A joint meeting of the Sections of Teaching of the American Association of Economic Entomologists and the Entomological Society of America was held in the North Garden of the Hotel Bellevue-Stratford, Philadelphia, Pennsylvania, on December 16, 1952. The meeting was called to order at 1:30 P.M. by Chairman A. C. Hodson and the following program was presented, based upon the general topic "The Employers' View of Entomological Training."

1. Research and Development of Insecticides. HARRY F. DIETZ, *E. I. DuPont de Nemours & Co., Wilmington, Delaware.*
2. Insecticide Sales and Promotion. BRUCE D. GLEISSNER, *American Cyanamid Co., New York, N. Y.*
3. Pest Control Operators. WILLIAM O. BUETTNER, *National Pest Control Association, New York, N. Y.*
4. Experiment Stations. ROBERT L. METCALF, *California Citrus Experiment Station, Riverside, California.*
5. Bureau of Entomology and Plant Quarantine. FRED C. BISHOPP, *U. S. Bureau of Entomology and Plant Quarantine, Washington, D. C.*
6. University Teaching and Research. Clyde F. Smith, North Carolina State College, Raleigh, N. C.
7. U. S. Public Health Service. G. H. BRADLEY, *Communicable Disease Center, U. S. Public Health Service, Atlanta, Ga.*
8. Summary and Discussion. THOMAS C. WATKINS, *Cornell University, Ithaca, N. Y.*

Limited discussion took place following presentation of several of these topics. Sentiment was expressed from the floor favoring the publication of the ideas presented by the various speakers, but no means seemed to exist to carry out this request.

After the scheduled program had been completed, the Chairman called for the report of the Nominating Committee, consisting of Dwight M. DeLong and William P. Hayes. The Nominating Committee recommended the following nominees for the coming year: ROBERT L. USINGER, *University of California, Chairman;* PAUL O. RITCHER, *Oregon State College, Secretary.* Upon motion, duly seconded, these recommendations were approved and the meeting adjourned.

Respectfully submitted,
PAUL A. DAHM, *Secretary*

THE ENTOMOLOGICAL SOCIETY OF PENNSYLVANIA

THIRTIETH ANNUAL MEETING

January 14, 1953

The Thirtieth Annual Meeting of the Entomological Society of Pennsylvania was held in the Bureau of Plant Industry, State Capitol, Harrisburg, Pennsylvania, January 14, 1953 with S. G. Gesell presiding.

The following members and visitors were present:

James Nelson	R. B. Troxel
C. L. Morris	Noel C. Farr
M. W. Eddy	Cy Campbell
A. B. Champlain	Louis Perkins
Mancefield Barrow	L. E. Adams
J. O. Pepper	L. B. Pryor
T. L. Guyton	H. A. Strohecker
D. O. Van Denburg	W. C. Wheatfield
S. W. Frost	W. W. Clarke, Jr.
A. R. Jeffrey	H. B. Kirk
E. M. Craighead	George Shoemaker
H. W. Ridgway	S. G. Gesell
G. B. Sleesman	E. J. Udine

At the request of Dr. C. E. Palm, Dr. T. L. Guyton served as the official representative of the Entomological Sodiety of America.

During the business meeting, D. O. Van Denburg was elected to membership and the following were elected to offices in 1953:

President—NOEL C. FARR
Vice President—L. E. ADAMS
Secretary—E. J. UDINE

Mr. H. W. Ridgway was the guest speaker and his talk on greenhouse insects and insecticides brought out many unusual and interesting side lights garnered from his extensive experience in this field.

Following Mr. Ridgeway's talk the customary panel discussion, in which all members participate, took place. The following points of general interest were brought up.

T. L. Guyton discussed oak wilt disease in Pennsylvania and stated that the infection is heaviest in the south central section. During the year, 184 infected trees were destroyed. A. R. Jeffrey discussed airplane scouting and D. O. Van Denburg gave a report on suspected insect vectors. Evidence pointed to bark and sap beetles as possible disseminators.

J. O. Pepper stated that two pests new to Pennsylvania were reported during the year. These were the tomato russet mite *Vasates destructor* (Keif.) and the alfalfa weevil *Hypera postica* (Gyll.). Mr. Pepper also discussed the problems of fruit flies in tomato processing plants.

Cy Campbell reported a new infestation of gypsy moth *Porthetria dispar* (L.) near Quakertown. He also stated that no moths have been recovered from any of the treated areas.

An excellent "Field Report" movie on the meadow spittle bug was shown by Mancefield Barrow, representative of the Hercules Powder Company.

The meeting adjourned at 5:00 P.M.

E. J. UDINE, *Secretary*

THE GEORGIA ENTOMOLOGICAL SOCIETY ANNUAL MEETING, 1952

The Georgia Entomological Society met in Savannah, Georgia, on March 7–8, 1952. Sixty-five of the ninety active members attended to hear addresses or papers by retiring president, W. G. Bruce, distinguished visitors, Dr. E. F. Knipling, Dr. M. D. Farrar, and Mr. Norman Allen, and by 18 members of the Society.

Committees were appointed as follows:

Auditing: C. M. BECKHAM, O. K. FLETCHER, H. N. POLLARD
Resolutions: O. I. SNAPP, W. E. BLASINGAME, THOMAS DUCK
Nominating: M. R. OSBURN, J. C. ALDEN, C. C. FANCHER

Dr. A. D. Hess escorted the group attending the annual banquet on a verbal and pictorial trip through the Islands of the Caribbean Sea and South and Central America.

Officers elected were: W. F. TURNER, *President;* W. E. BLASINGAME, *Vice-president;* H. O. LUND, *Secretary-Treasurer;* and P. W. FATTIG, *Historian.*

The state of the treasury was as follows:

Total credits.....	$149.58
Total debits.....	28.26
Cash on Hand.....	121.32

Twenty members and their wives joined the tour of the Savannah laboratories of the U.S.B.E.P.Q. and the U.S.P.H.S. Communicable Disease Center.

Respectfully submitted,
HORACE O. LUND
Secretary-Treasurer

DR. E. G. WEGENEK NEW RESEARCH COORDINATOR

The appointment of Dr. E. G. Wegenek as Research Coordinator for California Spray-Chemical Corporation was announced recently by Leo Gardner, Vice President and Manager of Research and Development. Dr. Wegenek was formerly the company's Field Research Entomologist in the Pacific Northwest.

Dr. Wegenek received a Ph.D. Degree in Entomology at the University of California in 1950. He secured his earlier technical training at the University of Kansas. Before joining California Spray-Chemical Corporation, he worked as research assistant in the Department of Entomology, University of California, Berkeley, California.

During World War II, Dr. Wegenek served as a Captain in the U. S. Air Force. As Research Coordinator, he will coordinate the field research activities of California Spray-Chemical Corporation for the Western United States, and will work out of Richmond, California, home office.

CORRECTION

ARMY INSECT CONTROL IN THE FAR EAST

"It is regretted that during the editing of the paper entitled 'Army Insect Control Operations in the Far East,' prior to its submission to the *Journal*, one statement was omitted. It should have been stated that *Culex tritaeniorhynchus, C. quinquefasciatus* and *C. pipiens* are implicated in the transmission of Japanese B. encephalitis which was the most serious insect-borne disease in Japan and one of the most serious in Okinawa. All three species of *Culex* and also *A. sinensis*, are considered to be carriers of filariasis." *Austin W. Morrill* (See article published in the April *Journal*, pp. 270–276, 1953.)

OBITUARY

Clarence R. Cleveland

Clarence R. Cleveland, 63, chief entomologist in the sales technical service department of Standard Oil Company (Indiana), died suddenly May 14.

Mr. Cleveland was in charge of development and technical service of insecticide, herbicide and fungicide products for Standard Oil, where he had worked since 1927.

He was awarded the B.A. degree at the University of Wisconsin in 1912, majoring in economic entomology. He served as conservation officer and lecturer for the Wisconsin Conservation Department in 1913 and 1914. From 1915 to 1921 he was assistant entomologist and assistant professor of economic entomology at the University of New Hampshire. From 1921 to 1927 he was assistant research entomologist for the Purdue university agricultural experiment station and assistant professor of entomology.

Mr. Cleveland was the author of many research and technical articles in scientific and trade journals. He wrote on pest control and industrial pesticide, especially on development and uses of petroleum insecticides,

He was a member of the American Association of Economic Entomologists; Sigma Xi; the National Shade Tree Conference, and was a fellow in the American Association for the Advancement of Science.

BOOK REVIEWS

MOSQUITOES OF THE NORTHWESTERN STATES, by H. H. Stage, C. M. Gjullin, and W. W. Yates. 1952. U.S.D.A. Agriculture Handbook 46. 95 pp., illus.

This is a companion to U.S.D.A. Misc. Pub. 336, THE MOSQUITOES OF THE SOUTHEASTERN STATES, by King, Bradley and McNeel. It follows the same plan and maintains the same high standards. In the area comprising Oregon, Washington and Idaho, thirty-nine species of mosquitoes have been recorded. Each species is treated from the standpoint of identification, distribution, biology, and importance to man. There are carefully prepared keys and diagrams which facilitate determination. Nine pages are devoted to groups of mosquitoes occurring in different ecological habitats. Mosquito control is thoroughly discussed, and the data on various insecticides will be useful to workers outside the Northwestern States. The bibliography of 175 references indicates the thoroughness with which the handbook was prepared.

WILLIAM E. BICKLEY

HANNA'S HANDBOOK OF AGRICULTURAL CHEMICALS. By Lester W. Hanna. Published by Lester W. Hanna, Rt. 1, Box 210, Forest Grove, Oregon. 1952. 8×5 inches. 219 p.+xvi p. 10 illus. $3.25.

This is a very useful handbook for one who has anything to do with fertilizers, fungicides, weed control, insecticides, rodent poisons, etc. Mr. Hanna has brought together descriptions of more than 500 commercial chemicals used in agriculture. These descriptive accounts include common and chemical names, chemical and physical properties, uses, formulations, toxicity, and antidotes in case of poisoning. Chapter 1 is concerned with antidotes in cases of poisoning; chapter 2 with oral toxicities of the newer agricultural chemicals in comparison with DDT and also with official tolerances of insecticide residues; chapter 4, with fertilizers; chapters five to nine, respectively, with fumigants, fungicides, herbicides, insecticides and rodenticides. Chapter 10 is a short one devoted to miscellaneous controls involving the use of actidione, electronics, electrovation, frostguards, bacteria, etc. The handbook closes with an index and a list of references.

Mr. Hanna has succeeded in condensing into brief accounts just the type and amount of information needed by the practical users of agricultural chemicals without scaring them away by too much chemistry. I can't imagine many housewives reaching for Mr. Hanna's handbook unless they have been reading the labels on their ant, roach, and bedbug remedies, but aside from these there are numerous other persons who should find in this handy reference book all the answers they need and should have in order to intelligently use agricultural chemicals, whether in large or small quantities.

H. B. WEISS

AUSTRALIAN TERMITES, by F. N. Ratcliffe, F. J. Gay and T. Greaves. Commonwealth Scientific and Industrial Research Organization, Australia. Melbourne, 1952. 124 pages, fig. 21 (mostly full-page plates), no index.

The crimson cover, decorated with an all-over pattern of large-jawed soldiers' heads, well expresses the menace implicit in tropical termites, of which this is an account of the biology, recognition and economic importance of the common Australian species. It represents, "to a very large extent, the result of the lifetime study of one man, Mr. G. F. Hill, who recently retired from the staff of the Division of Entomology, C.S.I.R.O. His monograph, "Termites (Isoptera) from the Australian Region" (1942), is the only comprehensive and authoritative work on Australian termites. As it is essentially a reference work for specialists," the present publication has been prepared for the "house-holders, builders, architects, engineers, and of course pest-control operators" who need a more simple presentation of the complicated and extensive data for "recognition of the relatively small number of economically important and destructive species." In reality, so many species must be described that it seems doubtful if any ordinary person will be able to surely identify the particular termites directly affecting his property, but selections make fascinating reading for anyone.

In Australia "termite damage to forest trees most commonly takes the form of a cylindrical 'pipe,' running up the center of the trunk. . . . In the eucalypts the first-formed (heart) wood is very prone to breakdown, and it is the normal practice to 'box out' and discard the central 4-inch square when a log is milled, and a considerable percentage of the termite pipes . . . does not necessarily mean that the recovery losses will be serious."

"The building powers of some of the grass-eating termites that occur on the aerodromes and emergency landing grounds in northern Australia have given rise to a serious problem. The construction of mounds by these subterranean colonies, and the rebuilding of leveled mounds is carried out with great rapidity (usually after rain); and structures quite large enough to endanger the safety of aircraft taking off or landing can be erected almost overnight."

"Perhaps the most remarkable of the termites' various activities is their habit of attacking the lead sheathing of subterranean telephone and electric cables. The perforation of the lead permits the entry of moisture, which ultimately results in a more or less serious breakdown of the insulation. Cable faults due to termite damage are sufficiently frequent to present a serious problem to the authorities concerned."

Only five pages are given for methods of control and eradication, which would seem hardly adequate. Indeed no mention is made of some of the newer insecticides which initial tests have indicated to be of such outstanding value that their use elsewhere has already become routine.

GEORGE N. WOLCOT

THE CHEMISTRY AND ACTION OF INSECTICIDES, by Harold H. Shepard. McGraw-Hill Book Company, Inc. 504 pp., 22 illus., tables. 1951.

To the host of economic entomologists who are well acquainted with the 1939 mimeographed edition of *The Chemistry and Toxicology of Insecticides*, this book will not seem unfamiliar in style of presentation, as it is an outgrowth of the earlier work, but rewritten and reorganized. It has a somewhat historical approach, anticipated by a tabloid citing insecticidal discoveries and events over a period of almost 3,000 years.

Approximately two-thirds of the book is devoted to discussions of individual materials having insecticidal value. These include the inorganic chemicals, organo-metallic compounds, oils, soaps, creosotes, plant products, and synthetic organic compounds. The arsenical compounds, fluorine compounds, sulfur compounds, and copper compounds are given prominence, and separate chapters are devoted to each group. One chapter is devoted to nicotine and other alkaloids, and another to pyrethrins, rotenone, and miscellaneous plant extractives. Two chapters are devoted to synthetic organic insecticides.

The remaining one-third of the book is devoted to a general discussion of chemical control, relative toxicity and mode of action of insecticides. An appendix includes some fourteen miscellaneous tables, most important of which is one giving a comparison of toxicities of a number of insecticides to a variety of insect species. This table is not so complete as it could be, and in fact, similar information is given in table form in several other places in the book.

A truly comprehensive work covering this field would necessarily be encyclopedia in nature. So it is to be expected that the author has been selective in his source material, and it is inevitable that omissions are made which are considered important by others. The text is very readable and well documented, and the typography is excellent.

The names of chemicals by which they are best known are commonly used, and confusion in nomenclature is largely avoided by reference to other names. Structural formulas are freely included. The insects referred to are indexed by their common names which are most useful in this type of work.

The stated purpose of the book is to consider properties of insecticides and not details of insect control. In general this is very well achieved, but one finds occasional hints of these details. A number of the tables in the appendix could well be left to a manual dealing specifically with insect control. thereby making room for expansion of certain areas treated too sketchily.

When viewed in historical perspective, the emphasis on the older insecticides may be thoroughly justified. At the moment, and in view of the accumulation of information during the past decade, the synthetic organic chemicals of recent development seem to deserve more attention than was given them.

Undoubtedly the publisher's deadline prevented some late material from being incorporated in the book. Incidental reference is made to allethrin but it is not named. No specific mention is made of systemic insecticides as such, and the newer chemicals showing promise in this field are not included.

The book will be particularly useful in providing a ready reference to a multiplicity of insecticides and the elements of their chemistry, source, economic importance, and toxicology, and will occupy an important position in the libraries of students and workers in insect toxicology.

The above is the title of a report that appeared in The Journal of the American Medical Association May 24, 1952, vol. 149, pp. 367–9. This report, prepared by the Committee on Pesticides, is of interest to entomologists, because it is an evaluation of the available data on the subject. It deals with the dangers of sustained exposure to vapors generated by thermal insecticide dispensers. The vapors or fumes of the insecticides recrystallize on ceilings walls, and exposed surfaces and loose crystals may fall to horizontal surfaces. It appears also that the atmospheric dispersal of insecticide vapors is irregular and concentrations breathed in by exposed persons might exceed safe levels over prolonged periods of time. Several representative cases of poisoning are reported such as generalized urticaria developed by a woman after the installation of an automatic thermostatically controlled vaporizing device, at her place of employment, which dispensed lindane. Other patients experienced peripheral neuritis, headache, nausea, irritation of eyes, nose and throat after exposure to such vaporizers. The report calls attention to the need for more regulation of devices that violate accepted health practices and for the need of such devices, to meet safety specifications set up by state authorities. Local health officers are in the best position to see and correct practices that are against public health.—H. B. W.

ECOLOGICAL ANIMAL GEOGRAPHY. Second Edition. W. C. Allee and Karl P. Schmidt. An authorized edition, rewritten and revised. Based on Tiergeographie auf oekologischer Grundlage by the late Richard Hesse. New York, John Wiley & Sons, Inc. 1951. 9×5¾ inches. xiv+715 pp. 142 figs. $9.50.

The first American edition of this standard and well-known work was published in 1937. Although the present second edition is still more independent of the German original, because large amounts of the original remain, the authors have retained Professor Hesse's name on the title page. In view of the material that has been incorporated however, the work is practically new. Both authors are well-known, highly trained, experienced ecologists of recognized ability and their book is a readable and interesting account of the ecological basis of animal geography. Part 1, consisting of 9 chapters is devoted to the ecological foundations of zoogeography, involving the conditions of existence for animals, the effect of environmental selection on their distribution, barriers, means of dispersal, effects of geographic isolation, and biotic communities. Part 2, in 6 chapters is concerned with the distribution of marine animals, including the physical conditions in the ocean in relation to animal life, chemistry of the sea, biotic divisions of the ocean, the animal communities at great depths and the geographic divisions of the animal communities of the sea. Part 3 covers the distribution of animals in inland waters in 4 chapters and Part 4 in 9 chapters, the distribution of land animals. In the fourth and last part, one finds consideration of forest, grassland, desert and swamp communities, of animal life in polar regions, of island communities, of subterranean animal life and of the effect of man on the distribution of other animals. Each chapter is followed by a bibliography. This notice is but a brief indication of the wealth of material presented in this well-balanced, authoritative volume.—H. B. W.